savannah river site

interoffice memorandum

SED-GTE-2008-002

29 February 2008

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FROM: L.A. BAGWELL, 730-4B
M.R. MILLINGS, 773-42A

REVIEW OF THE TAN CLAY CONFINING ZONE BENEATH Z AREA

As you requested, we have reviewed and interpreted new and pertinent subsurface geologic data for Z Area. The results of this effort supplement and confirm previous interpretations regarding the Tan Clay Confining Zone beneath the Z Area (Saltstone) site.

Background

The Z Area Performance Assessment (MMES, 1992) and its associated special analyses and contaminant transport models (WSRC, 2004) rely on an understanding of the subsurface geologic and hydrodynamic conditions at the Saltstone site. Contained within the Dry Branch Formation, the hydrostratigraphic unit known (at SRS) as the Tan Clay Confining Zone (TCCZ) is of particular interest because it acts locally as an aquitard, supporting a water table and retarding the downward flow of groundwater. The presence or absence, thickness, and extent of this unit are important inputs into contaminant transport simulations that are used to establish Saltstone inventory limits and demonstrate expected compliance with applicable groundwater regulatory requirements.

During the more than 15 years since the original Z Area Performance Assessment (PA) was published, new boreholes have been completed at the Saltstone site and significant additional data have been acquired from this location. This report summarizes the interpretation of these additional geologic data, focusing on the TCCZ, within the context of previous interpretations.

Chronology

The site-specific stratigraphic and hydrogeologic conclusions of the original Z Area PA (MMES, 1992) were based primarily on boring logs and water levels from a series of well boreholes in and near Z Area. Later work (WSRC, 1997) used detailed, foot-by-boot core descriptions, sieve analyses, and borehole geophysical data to establish a regional hydrogeologic framework and groundwater flow model for the entire General Separations Area (GSA), of which Z Area is a part. Subsequent to the publication of the GSA framework and model, many cone penetrometer tests (CPTs) have been completed at Z Area, yielding important new subsurface data that improve our understanding of the stratigraphy beneath Saltstone. Figure 1 shows the locations of CPTs and boreholes interpreted for this effort. Table 1 lists the data types available for these boreholes and CPT locations.

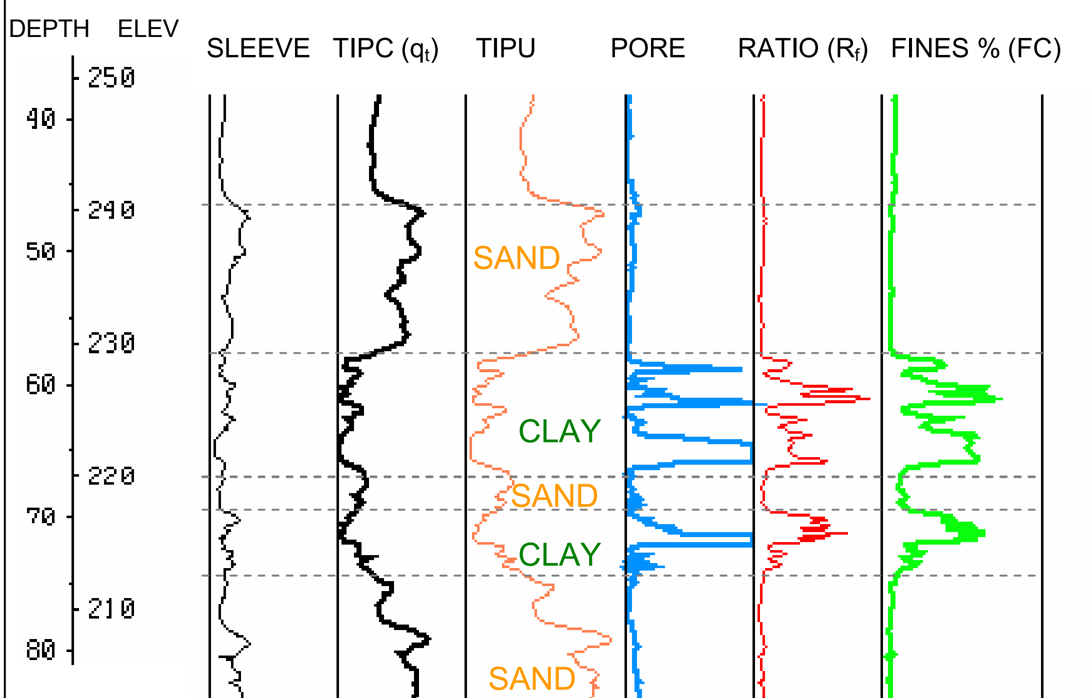
The Cone Penetrometer Test (CPT) Method

The CPT advances an electro-mechanical probe into the subsurface at a steady rate, acquiring measurements of cone (tip) resistance, sleeve resistance, and pore pressure. These primary response data – and derived data for calculated fines content (Syms, 2002) and sleeve-to-tip friction ratio – vary according to the physical properties of the subsurface being penetrated by the probe. As opposed to drilling and recovering core for direct lithologic description and sieve analyses, the CPT is a faster method for collecting high resolution “inferred” lithology data. CPT data are especially reliable when augmented with one or more cored boreholes that establish “ground truth” for the subsurface zone of interest. The relatively recent completion of multiple CPTs at the Saltstone site provides this exact set of conditions to be exploited in refining the elevation and thickness of the TCCZ.

Data Interpretation

All CPT and borehole data indicated at Table 1 were compiled and correlated in SRS's Landmark StratWorks application using elevation (above mean sea level) as a common datum. Using previous interpretations, including the GSA model (WSRC, 1997), as guides for the expected elevation and thickness of the TCCZ, the newer CPT data were scrutinized for evidence of this clay unit. In greatly simplified terms, in interlayered sand and clay strata, CPT data that indicate the presence of clay include lower tip stress, variously increased pore pressure, higher friction ratio, and increased calculated fines content, as shown in the illustration below.

Typical CPT Responses in Interlayered Sands and Clays



$$FC = [3.58 - \log(q_t))^2 + (\log)R_f) + 1.43)^2]^{1.765}$$ (Syms, 2002)

Results

Our interpretation indicates that the TCCZ is present in every borehole and CPT evaluated at the Saltstone site, ranging from 4.7 to 14.8 feet thick, with an average thickness of 10 feet. This interpretation agrees favorably with TCCZ thicknesses throughout the GSA as established by many previous studies (e.g., Aadland et al., 1995; Fallaw and Price, 1995; WSRC, 1995; WSRC, 1991).

As a check on this interpretation, the coordinate locations for the new CPTs were input to the GSA/PORFLOW model (WSRC, 2004), and the model was queried to predict the expected TCCZ elevation and thickness. Table 2 shows the results of both our interpretation and the model exercise. At most locations, the GSA/PORFLOW model predicts the 5.0 foot minimum thickness imposed during development of the model. In essentially every location, we interpret a thicker TCCZ than predicted by the model. We attribute this difference to the fact that the GSA/PORFLOW model was based on a relatively small dataset of Z Area borings. Also, because the model focuses on contaminant fate and transport, it is somewhat more "attuned" to hydrodynamic physical properties of aquifer vs. aquitard (e.g., hydraulic conductivity, permeability) whereas our interpretation more generously accommodates the TCCZ as several discrete, semi-continuous clay layers interbedded with sands and silts of the Dry Branch Formation. Appendix 1 is a series of CPT logs illustrating this point and showing our interpretations graphically.

References

Aadland, R.K., J.A. Gellici, and P.A. Thayer (1995), Hydrogeologic Framework of West-Central South Carolina, *Water Resources Division Report 5*, State of South Carolina Department of Natural Resources, Columbia, SC.

Fallaw, W.C, and V. Price (1995), Stratigraphy of the Savannah River Site and Vicinity, *Southeastern Geology*, 35 (1), pages 21-58.

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Syms, F.H. (2002), Calibration of the Electric Piezocone Penetrometer Sounding for Predicting Sediment Character and Geologic Mapping of Eocene Carolina Coastal Plain Sediments, Ph.D. dissertation, 146 pages, University of South Carolina, Columbia, SC.

WSRC (2004), Groundwater Flow Model of the General Separations Area Using PORFLOW, WSRC-TR-2004-00106, Westinghouse Savannah River Company, Aiken, SC.

WSRC (1997), Integrated Hydrogeological Model of the General Separations Area: Volumes I and II, Rev.0, WSRC-TR-96-0399, Westinghouse Savannah River Company, Aiken, SC.

WSRC (1995), Environmental Information Document – SRS Geology & Hydrogeology, WSRC-TR-95-0046, Westinghouse Savannah River Co., Aiken, SC.

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cc: H.H. Burns, 999-W
K.H. Rosenberger, 766-H

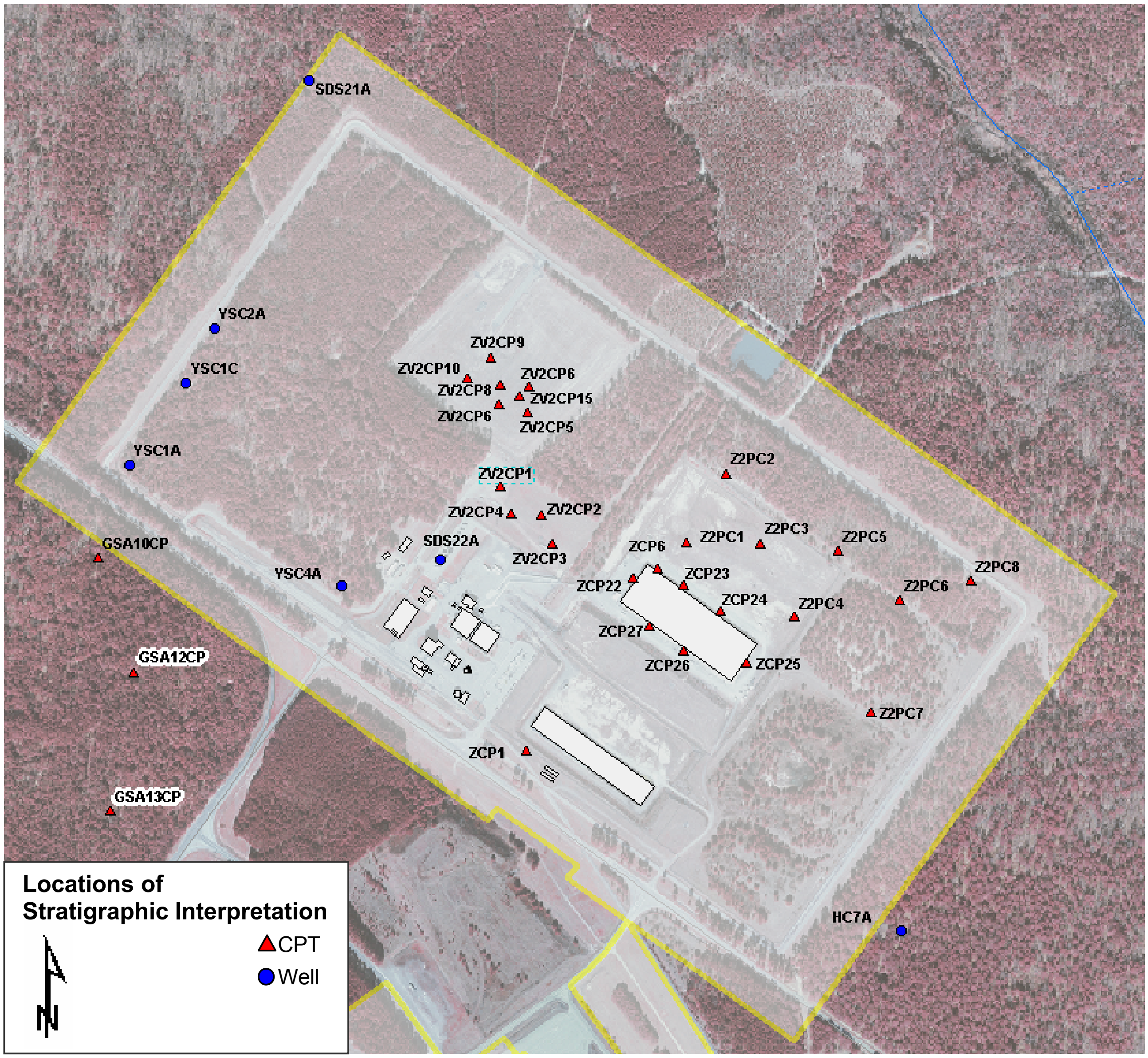


Figure 1. Locations of CPT Tests and Well Boreholes at Z Area

Table 1. Subsurface Data Available for Interpretation at Z Area

BOREHOLE	TYPE	DATA AVAILABLE: lithologic core description	borehole geophysics	CPT data	calculated fines content		
GSA10CP	well bore & CPT test		●	●			
GSA12CP	well bore & CPT test		●	●			
GSA13CP	well bore & CPT test		●	●			
HC7A	well bore	●					
SDS21A	well bore	●					
SDS22A	well bore	●					
YSC1A	well bore	●	●				
YSC1C	well bore	●	●				
YSC2A	well bore	●	●				
YSC4A	well bore	●	●				
Z2PC1	CPT test			●	●		
Z2PC2	CPT test			●	●		
Z2PC3	CPT test			●	●		
Z2PC4	CPT test			●	●		
Z2PC5	CPT test			●	●		
Z2PC6	CPT test			●	●		
Z2PC7	CPT test			●	●		
Z2PC8	CPT test			●	●		
ZCP1	CPT test			●			
ZCP22	CPT test			●			
ZCP23	CPT test			●			
ZCP24	CPT test			●			
ZCP25	CPT test			●			
ZCP26	CPT test			●			
ZCP27	CPT test			●			
ZCP6	CPT test			●			
ZV2CP1	CPT test			●	●		
ZV2CP10	CPT test			●	●		
ZV2CP15	CPT test			●	●		
ZV2CP2	CPT test			●	●		
ZV2CP3	CPT test			●	●		
ZV2CP4	CPT test			●	●		
ZV2CP5	CPT test			●	●		
ZV2CP6	CPT test			●	●		
ZV2CP7	CPT test			●	●		
ZV2CP8	CPT test			●	●		
ZV2CP9	CPT test			●	●		

Table 2. Interpreted and Modeled TCCZ Elevation and Thickness

					INTERPRETED TCCZ			MODELED TCCZ			DIFFERENCE		
BOREHOLE	GROUND ELEVATION	WELL_USE	UTM_E	UTM_N	TOP ELEVATION	BOTTOM ELEVATION	THICKNESS	TOP ELEVATION	BOTTOM ELEVATION	THICKNESS[b]	TOP ELEVATION[c]	BOTTOM ELEVATION[c]	THICKNESS[d]
GSA10CP	285.2	CPT-U	439811.0	3684985.2	209.3	196.8	12.5	213.2	204.0	9.2	3.9	7.1	-3.3
GSA12CP	286.7	CPT-U	439859.7	3684830.7	219.9	211.9	8.0	222.5	217.5	5.0	2.6	5.6	-3.0
GSA13CP	289.1	CPT-U	439827.0	3684642.6	214.8	202.8	12.0	214.4	209.1	5.4	-0.4	6.3	-6.6
HC7A[a]	277.0	ABANDONED	440897.3	3684480.2	223.0	217.1	5.9	207.0	202.0	5.0	-16.0	-15.1	-0.9
SDS21A[a]	251.1	ABANDONED	440095.9	3685630.2	206.1	196.1	10.1	204.5	198.5	6.0	-1.6	2.4	-4.1
SDS22A[a]	286.0	ABANDONED	440273.2	3684981.3	219.9	213.1	6.8						
YSC1A[a]	268.9	ABANDONED	439853.3	3685110.2	211.1	198.9	12.2	209.9	198.9	11.0	-1.2	0.0	-1.2
YSC1C[a]	272.5	MONITORING WELL	439929.7	3685220.9	212.1	201.7	10.4	214.5	209.5	5.0	2.4	7.8	-5.4
YSC2A[a]	281.7	ABANDONED	439967.5	3685295.7	219.4	214.7	4.7	219.7	214.7	5.0	0.3	0.0	0.3
YSC4A[a]	287.5	ABANDONED	440140.3	3684946.1	220.2	210.1	10.1	222.5	213.5	9.0	2.3	3.4	-1.1
Z2PC1	271.7	SCPT-U	440607.2	3685005.5	230.7	216.9	13.8	225.6	220.6	5.0	-5.1	3.7	-8.8
Z2PC2	278.5	SCPT-U	440661.6	3685099.0	221.5	207.4	14.0	227.3	222.3	5.0	5.8	14.9	-9.0
Z2PC3	270.7	SCPT-U	440706.3	3685004.5	215.7	204.8	10.9	226.0	221.0	5.0	10.3	16.2	-5.9
Z2PC4	268.7	SCPT-U	440753.7	3684906.3	217.7	212.6	5.1	224.7	219.7	5.0	6.9	7.1	-0.1
Z2PC5	264.1	SCPT-U	440813.1	3684994.5	228.8	222.2	6.6	223.4	218.4	5.0	-5.4	-3.8	-1.6
Z2PC6	258.4	SCPT-U	440896.4	3684927.7	219.5	213.7	5.8	218.3	213.3	5.0	-1.2	-0.4	-0.8
Z2PC7	270.6	SCPT-U	440857.6	3684776.5	215.7	207.9	7.8	221.3	216.3	5.1	5.6	8.4	-2.8
Z2PC8	244.8	SCPT-U	440992.3	3684953.4	227.0	219.9	7.1	207.6	202.6	5.0	-19.3	-17.3	-2.1
ZCP1	291.9	CPT-U	440390.3	3684724.5	216.1	204.8	11.3	210.6	205.6	5.0	-5.5	0.8	-6.3
ZCP22	269.8	SCPT-U	440534.6	3684957.3	229.9	223.0	6.8	225.1	220.1	5.0	-4.8	-2.9	-1.8
ZCP23	271.3	SCPT-U	440602.7	3684949.6	220.9	214.1	6.9	224.5	219.5	5.0	3.5	5.4	-1.9
ZCP24	271.5	SCPT-U	440652.7	3684913.1	224.2	212.5	11.7	224.2	219.2	5.0	0.0	6.7	-6.7
ZCP25	269.6	SCPT-U	440688.6	3684843.9	223.4	214.8	8.7	223.2	218.2	5.0	-0.2	3.5	-3.7
ZCP26	269.6	SCPT-U	440603.3	3684859.3	228.3	217.8	10.4	223.0	218.0	5.0	-5.3	0.2	-5.4
ZCP27	269.7	SCPT-U	440557.1	3684892.8	217.6	210.2	7.4	223.5	218.5	5.0	5.9	8.3	-2.4
ZCP6	269.8	CPT-U	440567.7	3684970.9	227.3	218.7	8.6	225.2	220.2	5.0	-2.1	1.4	-3.6
ZV2CP1	288.6	SCPT-U	440355.0	3685082.7	222.0	207.2	14.8	214.6	209.6	5.0	-7.4	2.4	-9.8
ZV2CP10	279.0	SCPT-U	440310.5	3685228.3	227.6	213.5	14.1	219.6	214.6	5.0	-8.0	1.1	-9.1
ZV2CP15	281.0	SCPT-U	440380.9	3685204.1	221.0	208.9	12.1	222.9	217.9	5.0	1.9	9.0	-7.1
ZV2CP2	286.8	SCPT-U	440411.1	3685042.5	229.2	214.9	14.3	218.3	213.3	5.0	-10.9	-1.6	-9.3
ZV2CP3	286.9	SCPT-U	440426.5	3685004.7	231.4	223.5	8.0	217.8	212.8	5.0	-13.7	-10.7	-3.0
ZV2CP4	287.3	SCPT-U	440370.4	3685045.0	226.8	213.2	13.6	211.8	206.8	5.0	-14.9	-6.3	-8.6
ZV2CP5	287.0	SCPT-U	440391.9	3685182.7	226.6	215.0	11.6	224.0	219.0	5.0	-2.6	4.0	-6.6
ZV2CP6	282.8	SCPT-U	440354.3	3685193.4	229.5	221.1	8.4	222.4	217.4	5.0	-7.1	-3.7	-3.4
ZV2CP7	279.4	SCPT-U	440393.9	3685218.1	222.2	207.7	14.5	222.8	217.8	5.0	0.6	10.1	-9.5
ZV2CP8	278.8	SCPT-U	440355.6	3685219.6	223.4	211.3	12.1	221.5	216.5	5.0	-2.0	5.1	-7.1
ZV2CP9	275.3	SCPT-U	440342.4	3685256.4	211.2	197.7	13.5	219.7	214.7	5.0	8.5	17.0	-8.5
				MIN	206.1	196.1	4.7	204.5	198.5	5.0[a]		MIN (abs val)	0.1
				MAX	231.4	223.5	14.8	227.3	222.3	11.0		MAX (abs val)	9.8
				AVG	221.4	211.3	10.1	219.4	213.9	-----			-----
				STD DEV	6.5	7.3	3.0	6.1	6.6	-----			-----

Notes:
All elevations are in feet above mean sea level (ft msl); all thicknesses are in feet

(a) Ground truth points for the GSA/PORFLOW model
(b) Nominal thickness -- PORFLOW model assumes minimum 5' thickness
(c) Negative numbers indicate interpreted TCCZ boundary is shallower than modeled boundary.
(d) Negative numbers indicate interpreted TCCZ thicker than modeled.

Appendix 1

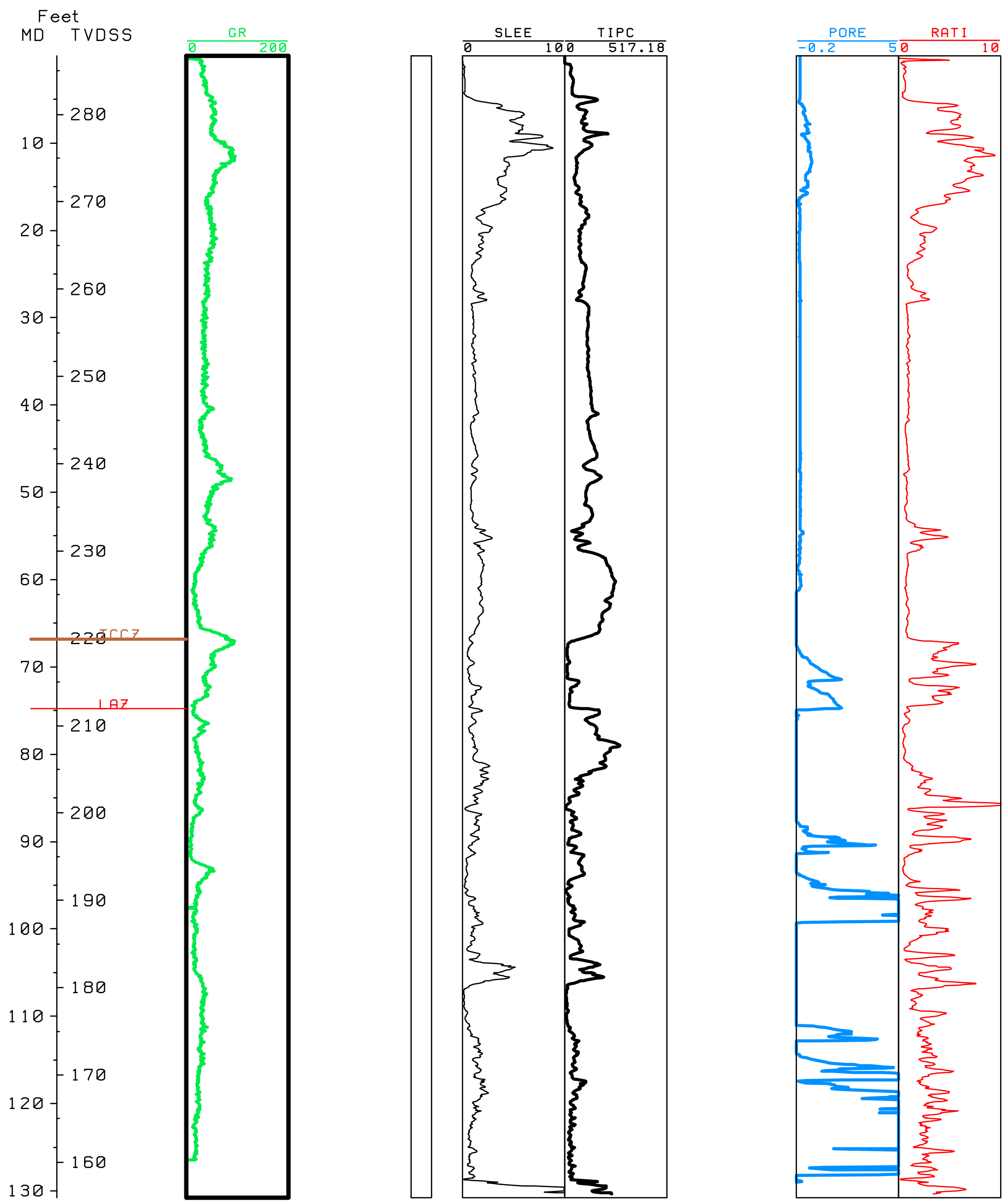
CPT Logs Showing Interpretation of TCCZ

(Note: The bottom boundary of the TCCZ is noted “LAZ” for Lower Aquifer Zone)

UWI: GSA12CP

ELEV: KB 286.7 FEET

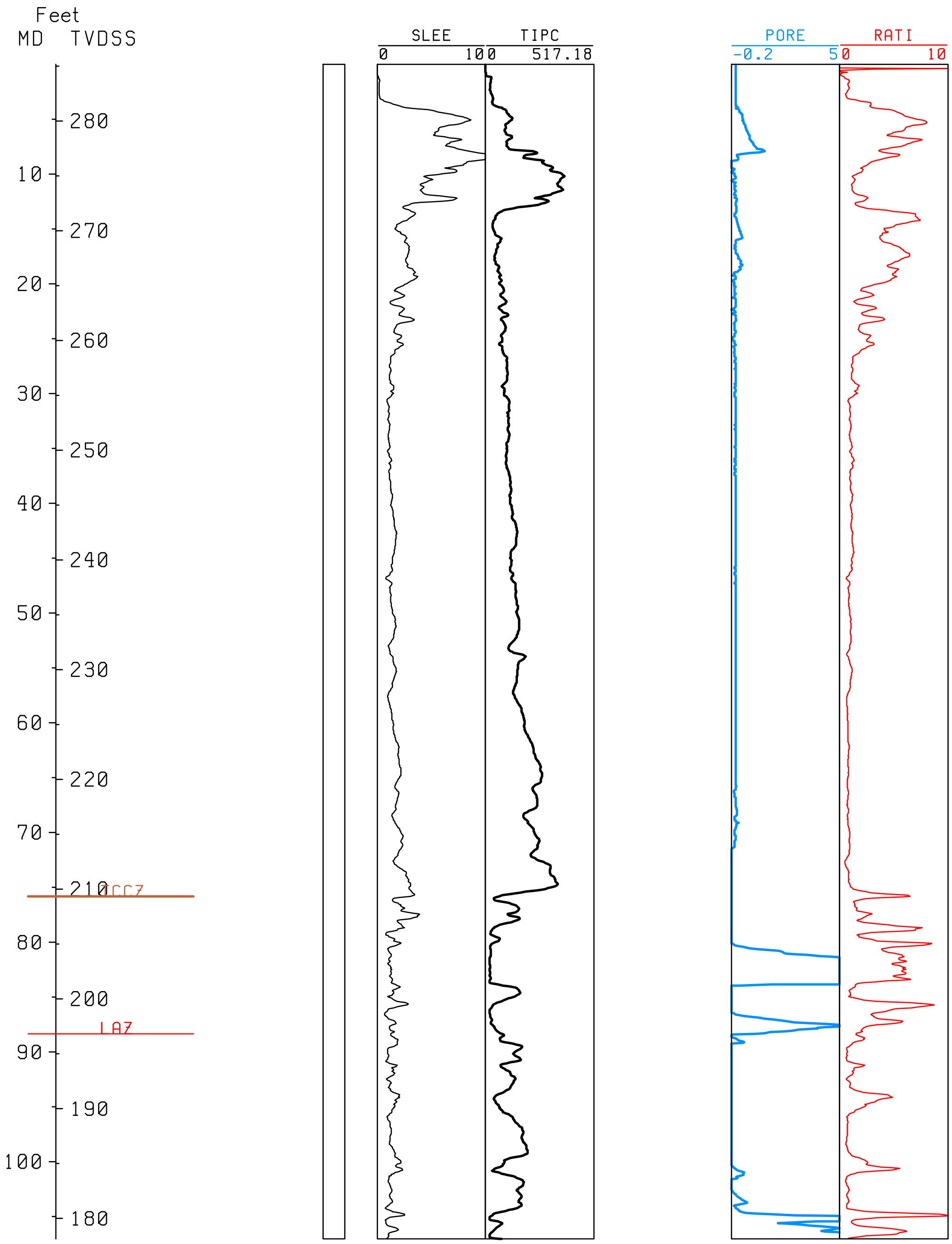
TD: 130.8 FEET MD



UWI: GSA10CP

ELEV: KB 285.2 FEET

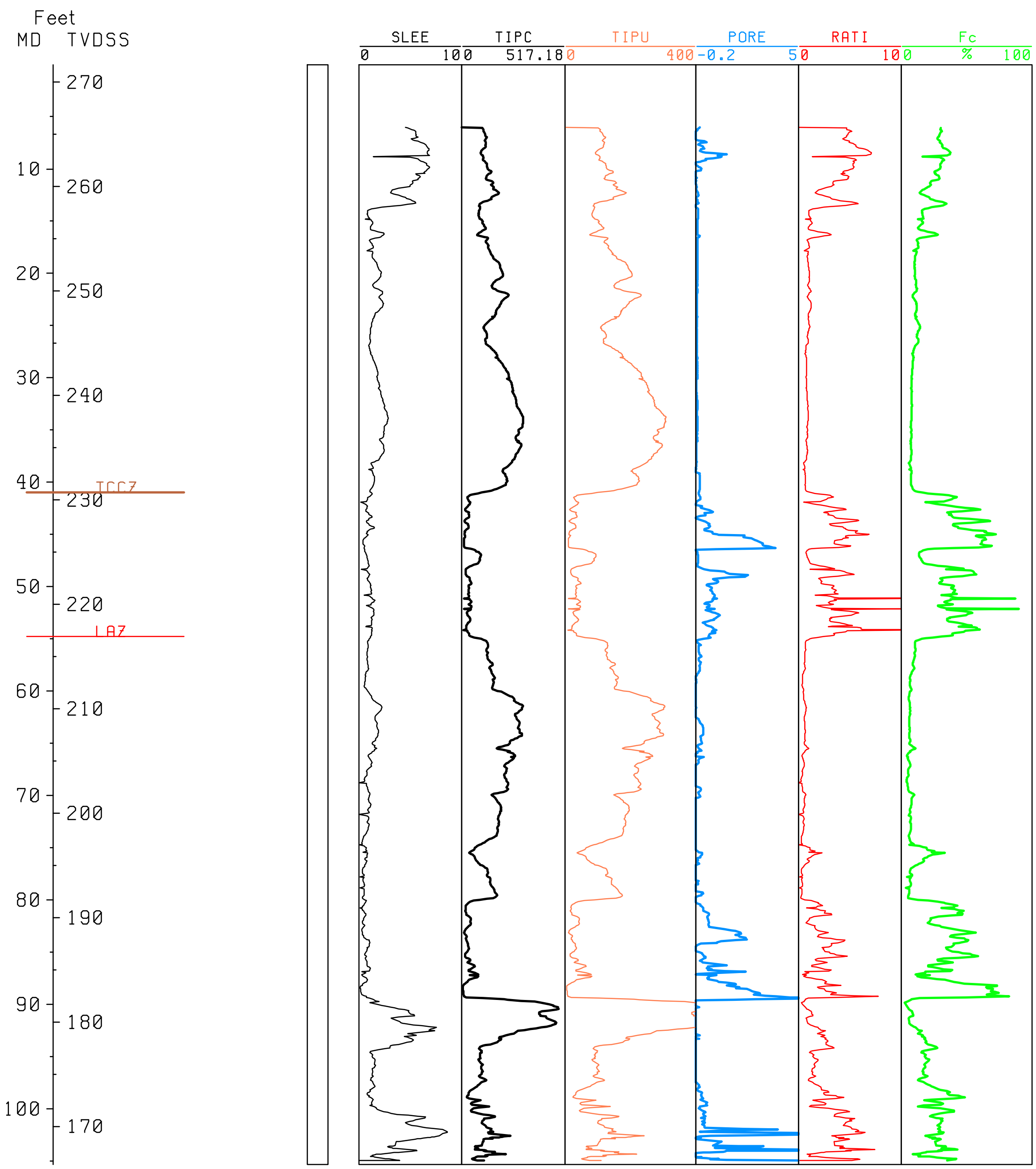
TD: 162.5 FEET MD



UWI: Z2PC1

ELEV: KB 271.7 FEET

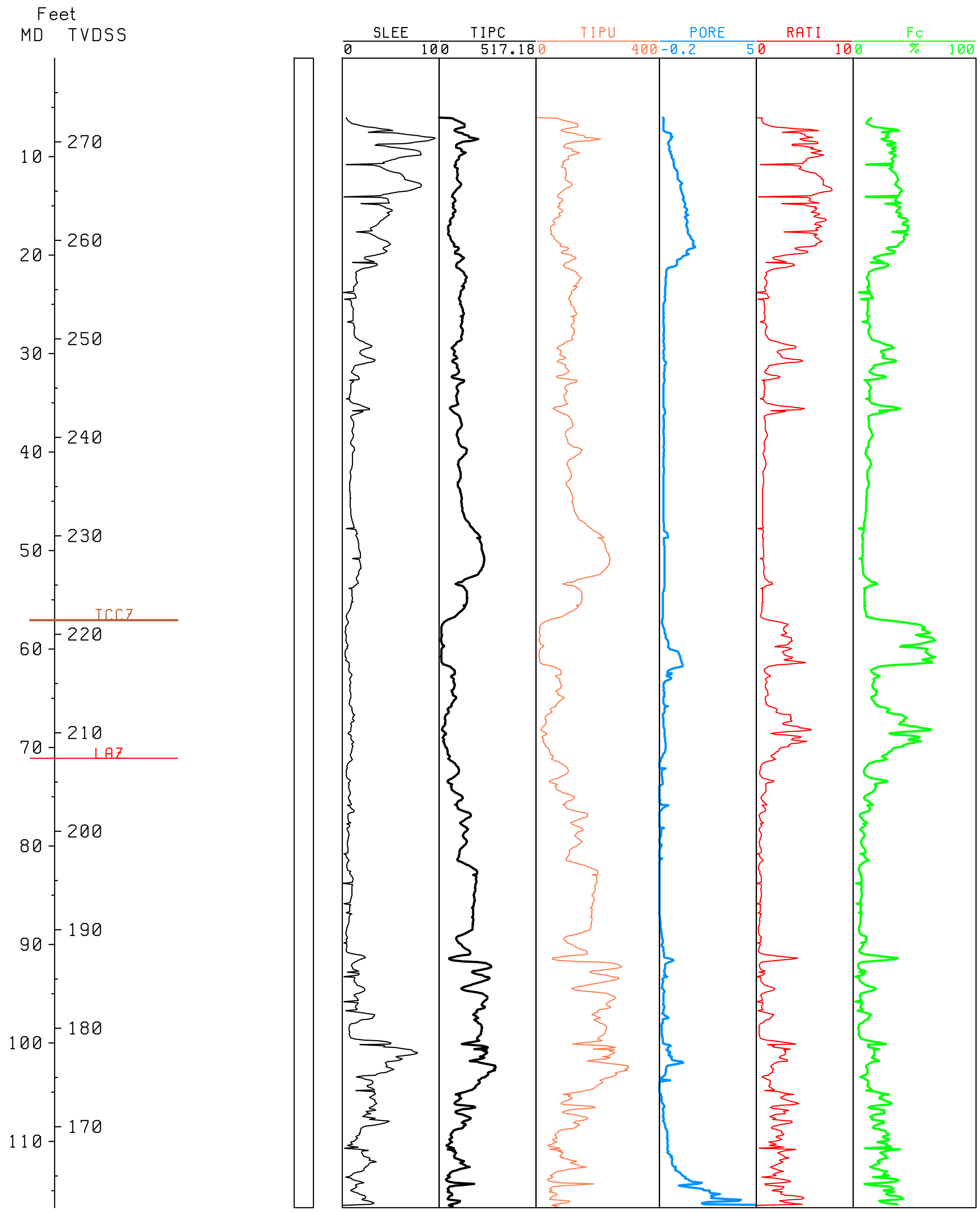
TD: 105.3 FEET MD



UWI: Z2PC2

ELEV: KB 278.5 FEET

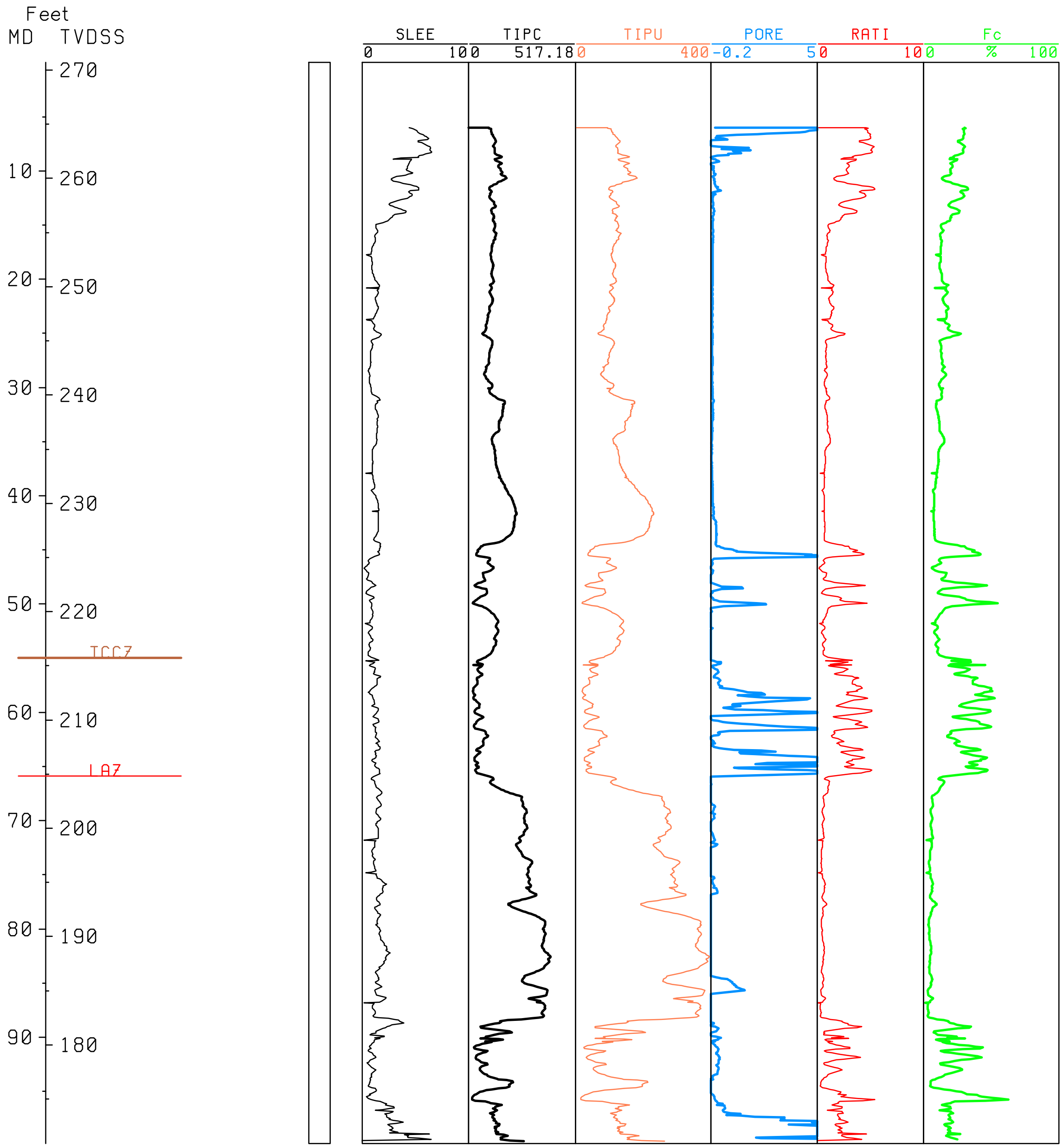
TD: 116.7 FEET MD



UWI: Z2PC3

ELEV: KB 270.7 FEET

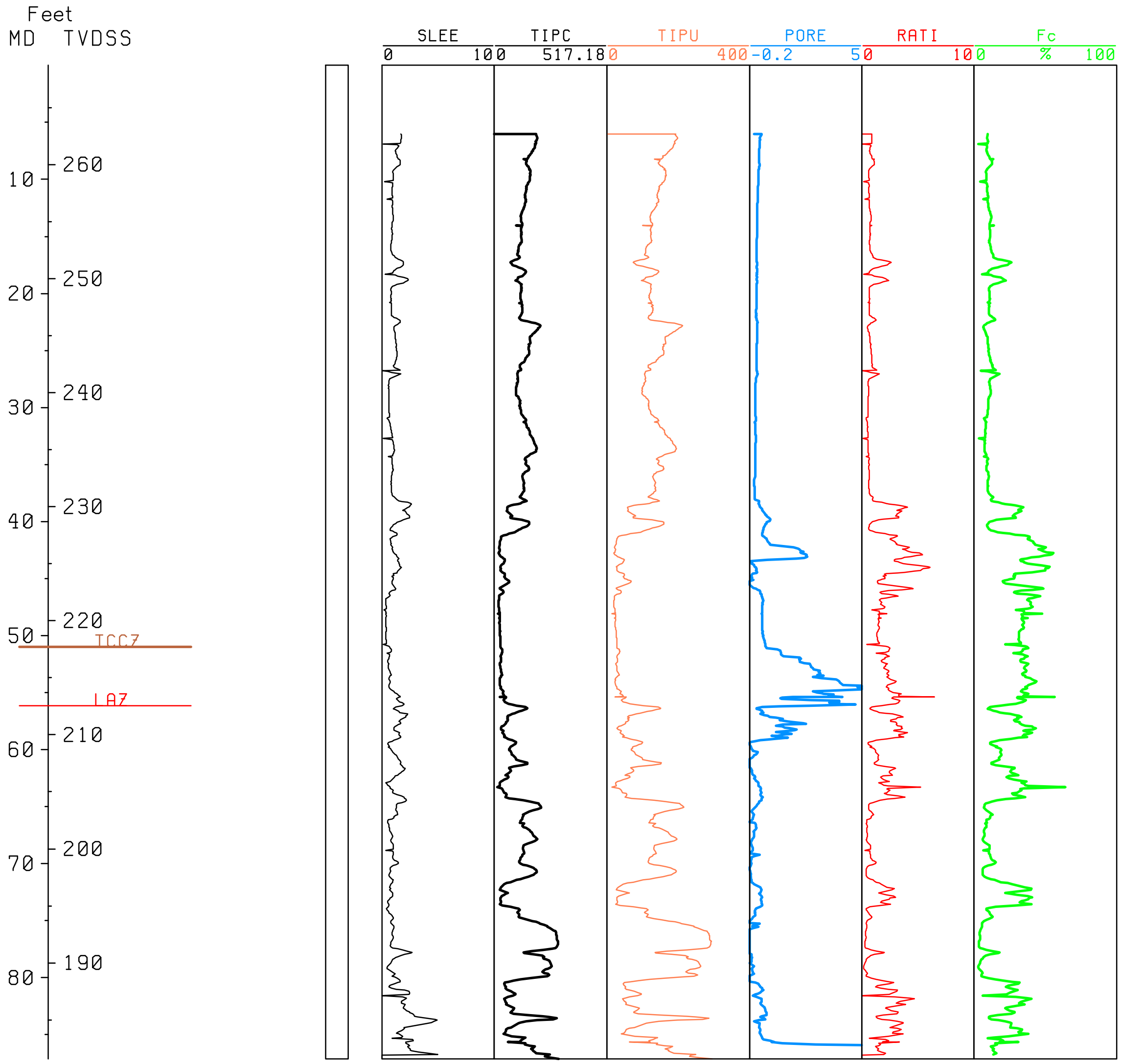
TD: 99.8 FEET MD



UWI: Z2PC4

ELEV: KB 268.7 FEET

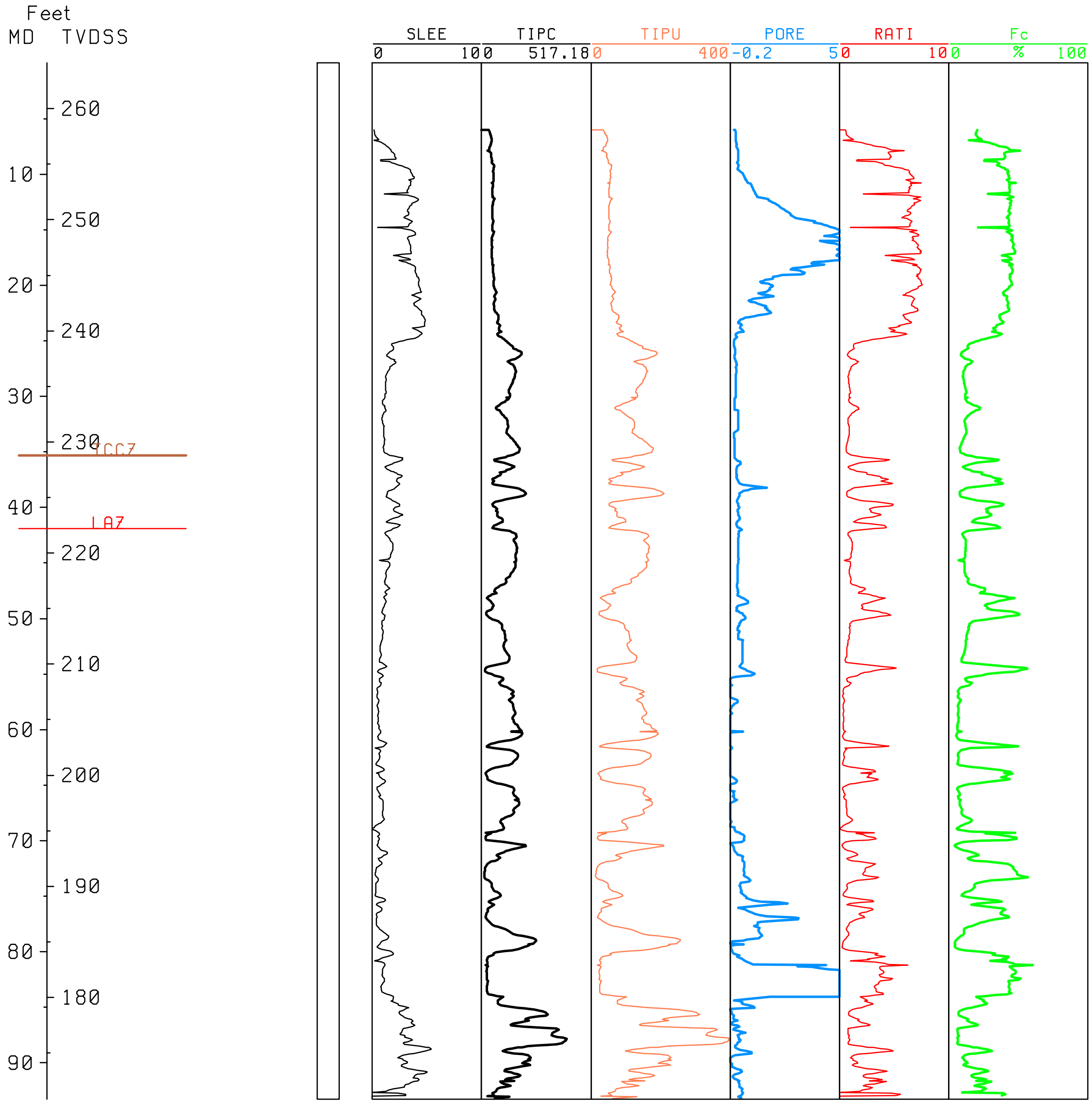
TD: 87.1 FEET MD

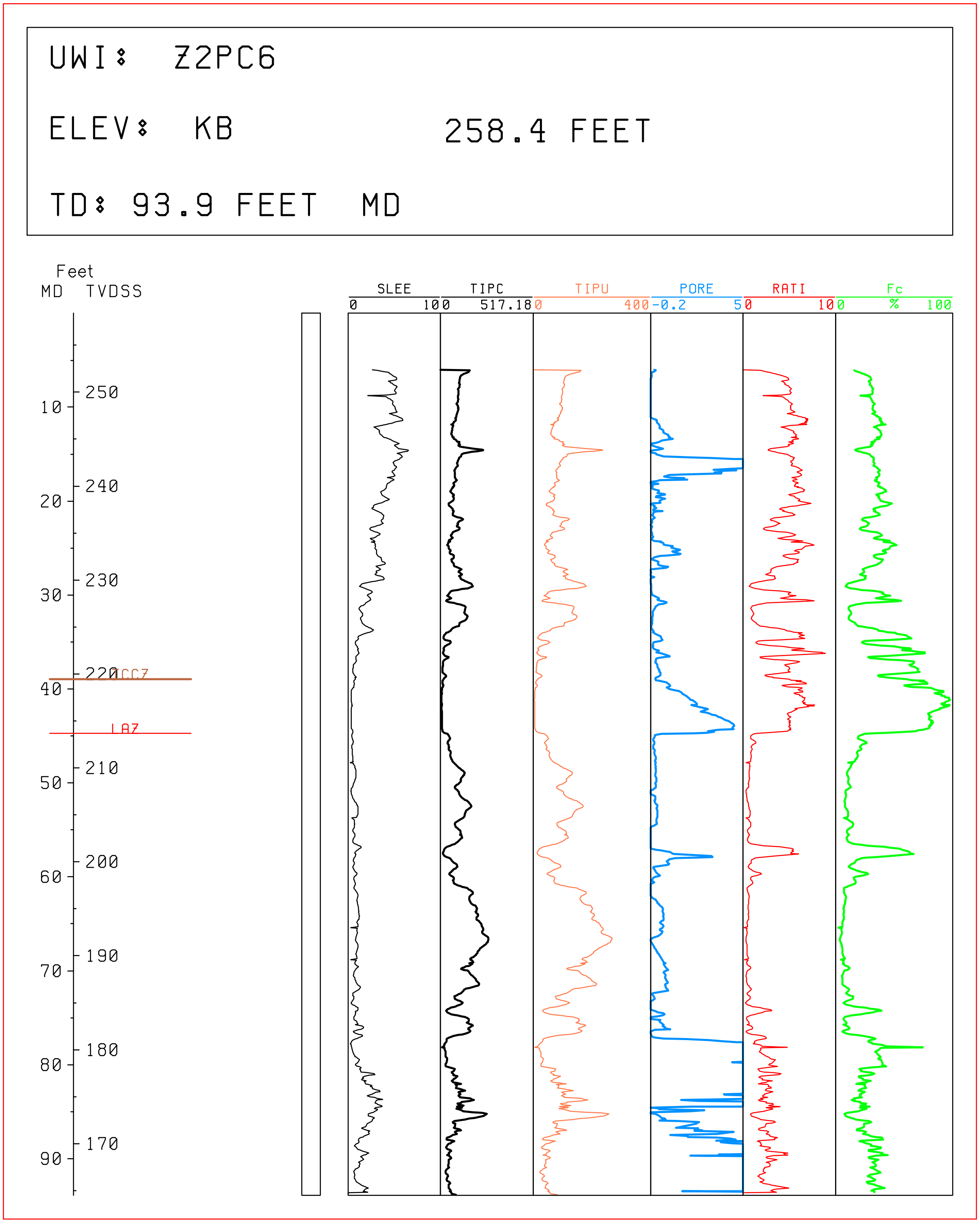


UWI: Z2PC5

ELEV: KB 264.1 FEET

TD: 93.3 FEET MD

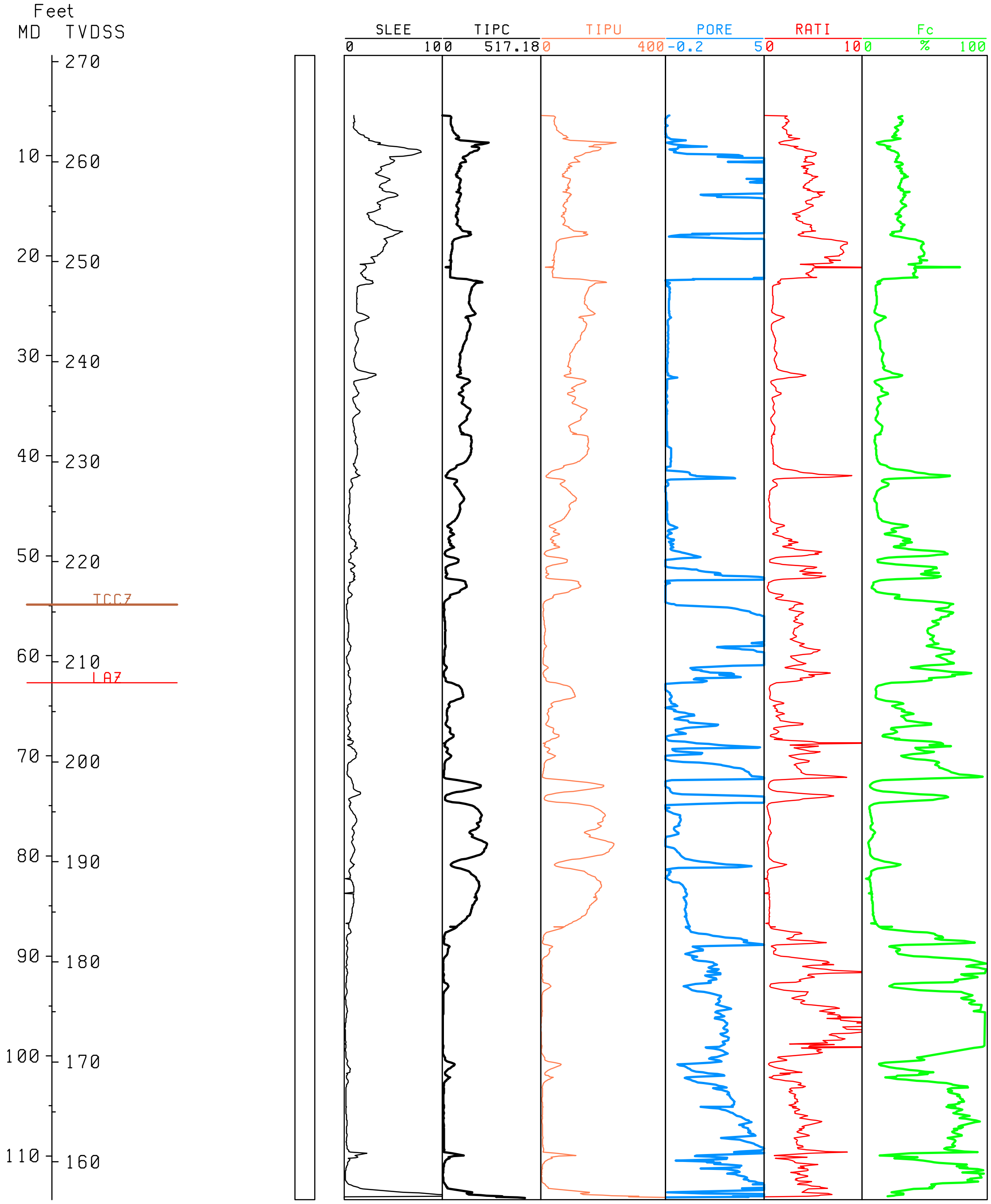


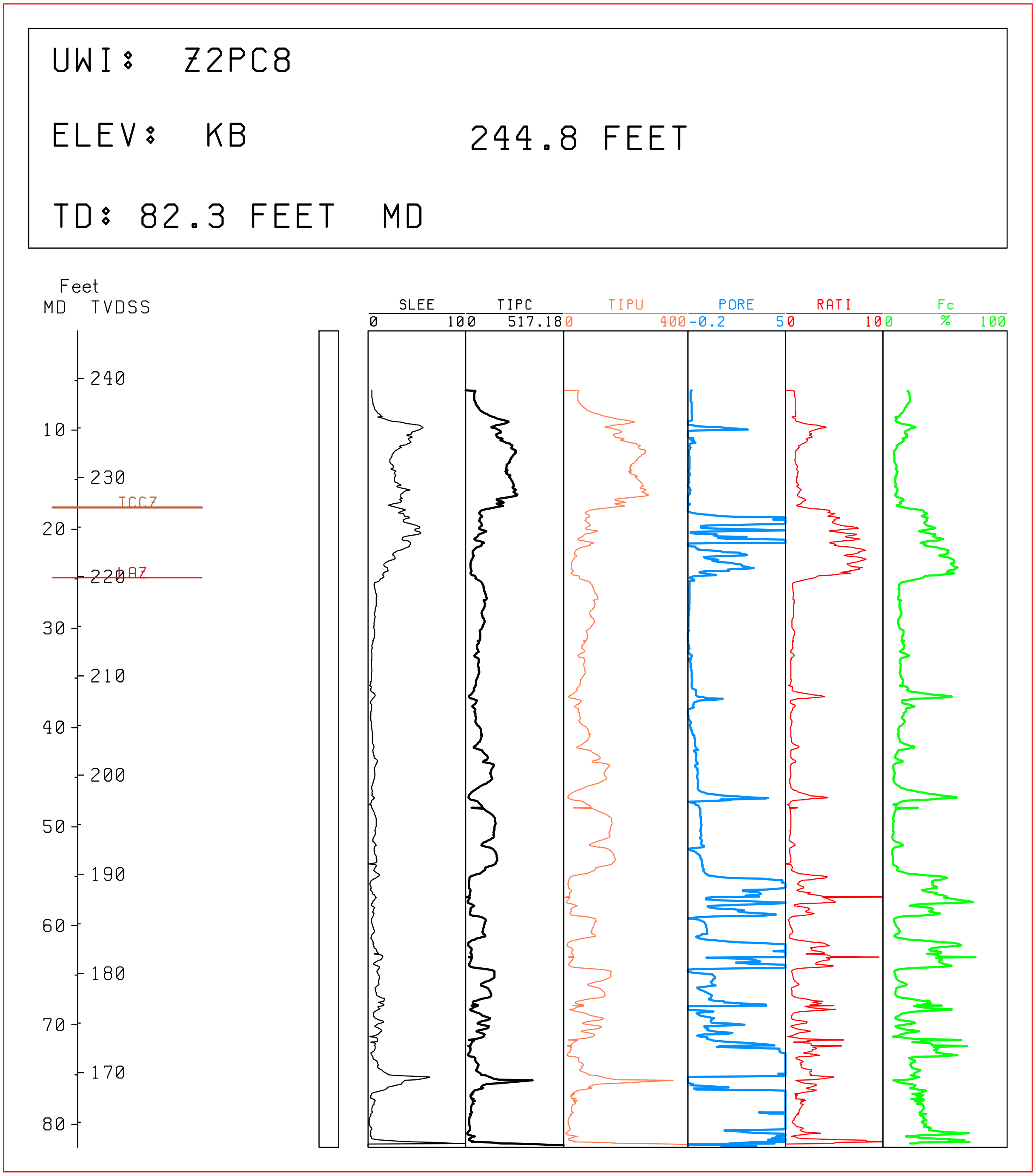

UWI: Z2PC6
ELEV: KB 258.4 FEET
TD: 93.9 FEET MD
Feet
MD TVDSS
SLEE
TIPC
TIPU
PORE
RATI
Fc
0 100
0 517.18
0 400
-0.2 5
0 10
0 % 100
250
240
230
220
210
200
190
180
170
10
20
30
40
50
60
70
80
90
CCZ
LAZ

UWI: Z2PC7

ELEV: KB 270.6 FEET

TD: 114.4 FEET MD

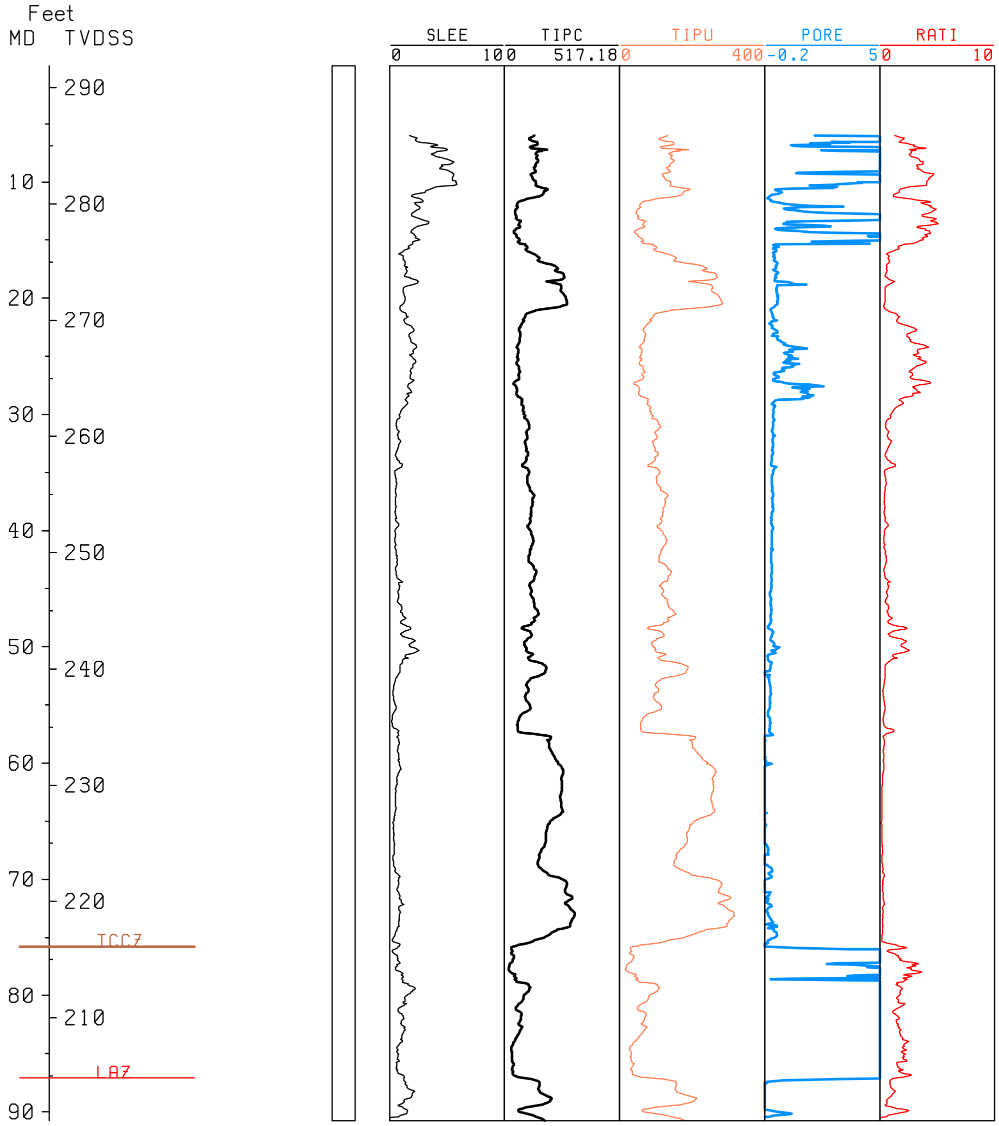



UWI: Z2PC8
ELEV: KB 244.8 FEET
TD: 82.3 FEET MD
Feet
MD TVDSS
240
10
230
TCCZ
20
220
LAZ
30
210
40
200
50
190
60
180
70
170
80
SLEE
0 100
TIPC
0 517.18
TIPU
0 400
PORE
-0.2 50
RATI
0 100
Fc
0 % 100

UWI: ZCP1

ELEV: KB 291.9 FEET

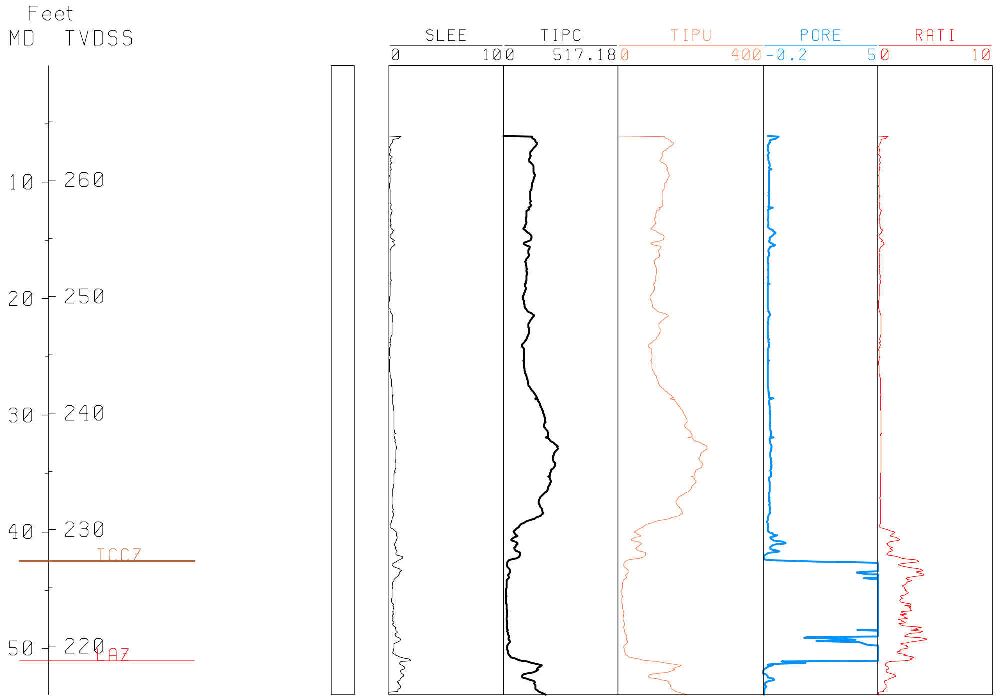
TD: 90.8 FEET MD

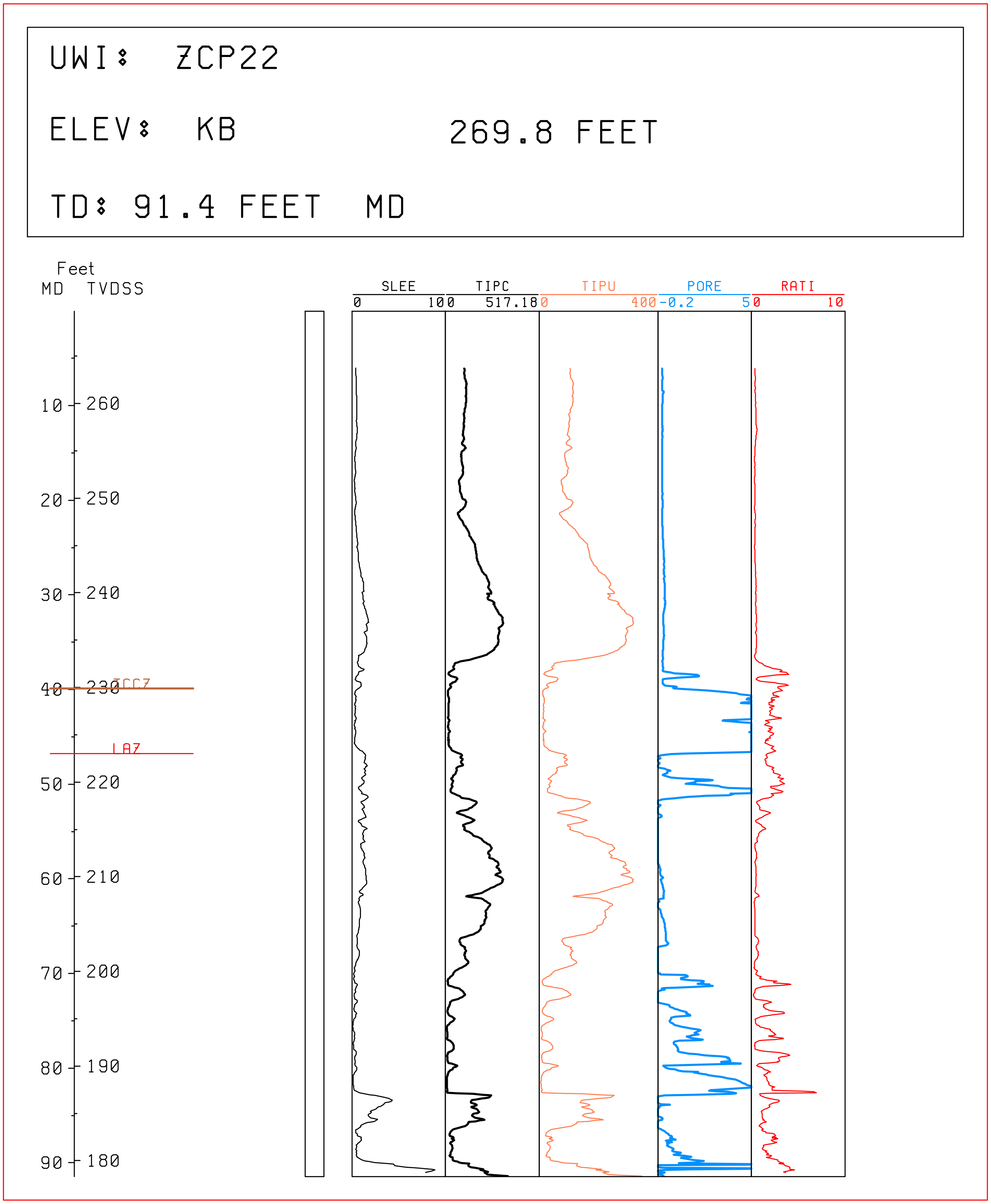


UWI: ZCP6

ELEV: KB 269.8 FEET

TD: 54.0 FEET MD

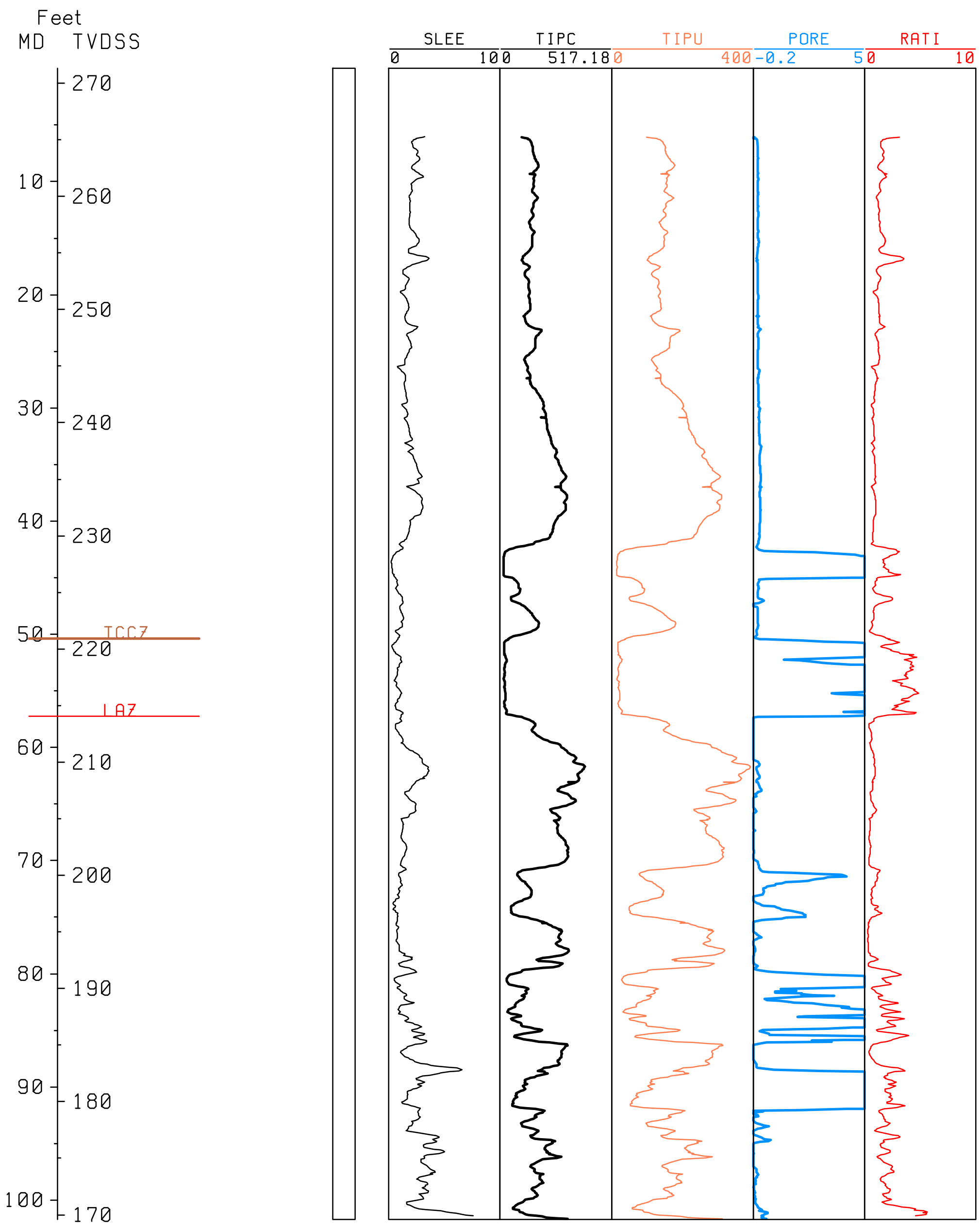



UWI: ZCP22
ELEV: KB 269.8 FEET
TD: 91.4 FEET MD
Feet
MD TVDSS
SLEE
0 100
TIPC
0 517.18
TIPU
0 400
PORE
-0.2 5
RATI
0 10
10 260
20 250
30 240
40 230
50 220
60 210
70 200
80 190
90 180
LAZ

UWI: ZCP23

ELEV: KB 271.3 FEET

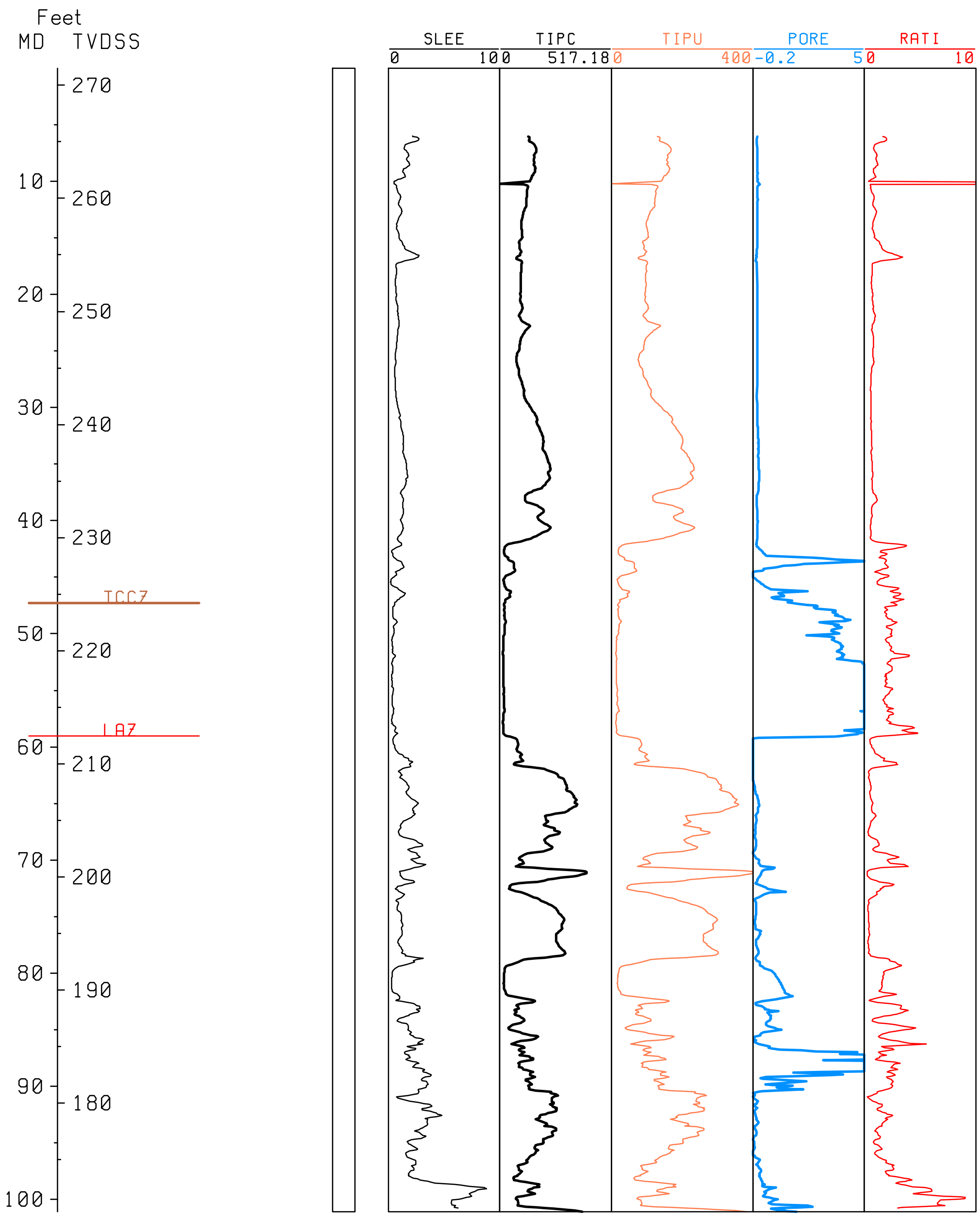
TD: 101.7 FEET MD



UWI: ZCP24

ELEV: KB 271.5 FEET

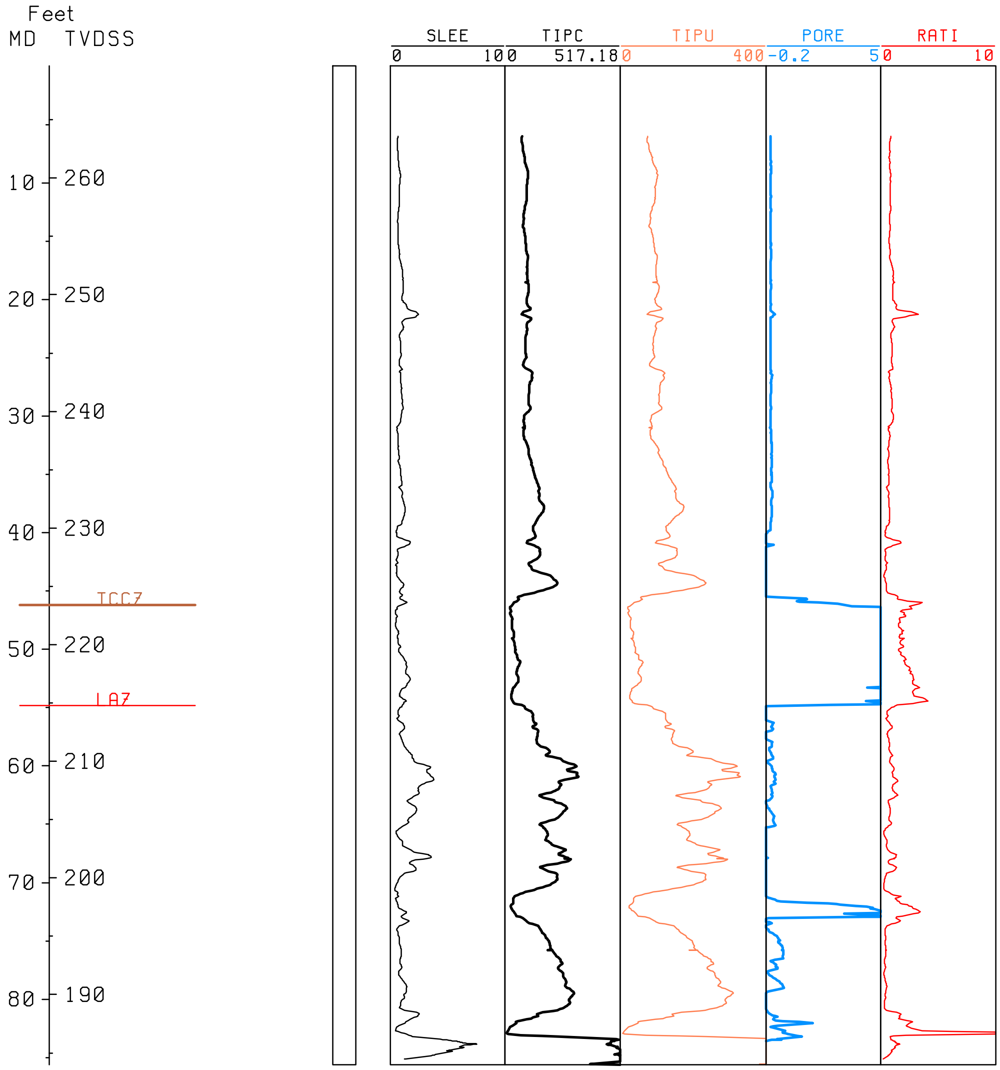
TD: 101.1 FEET MD

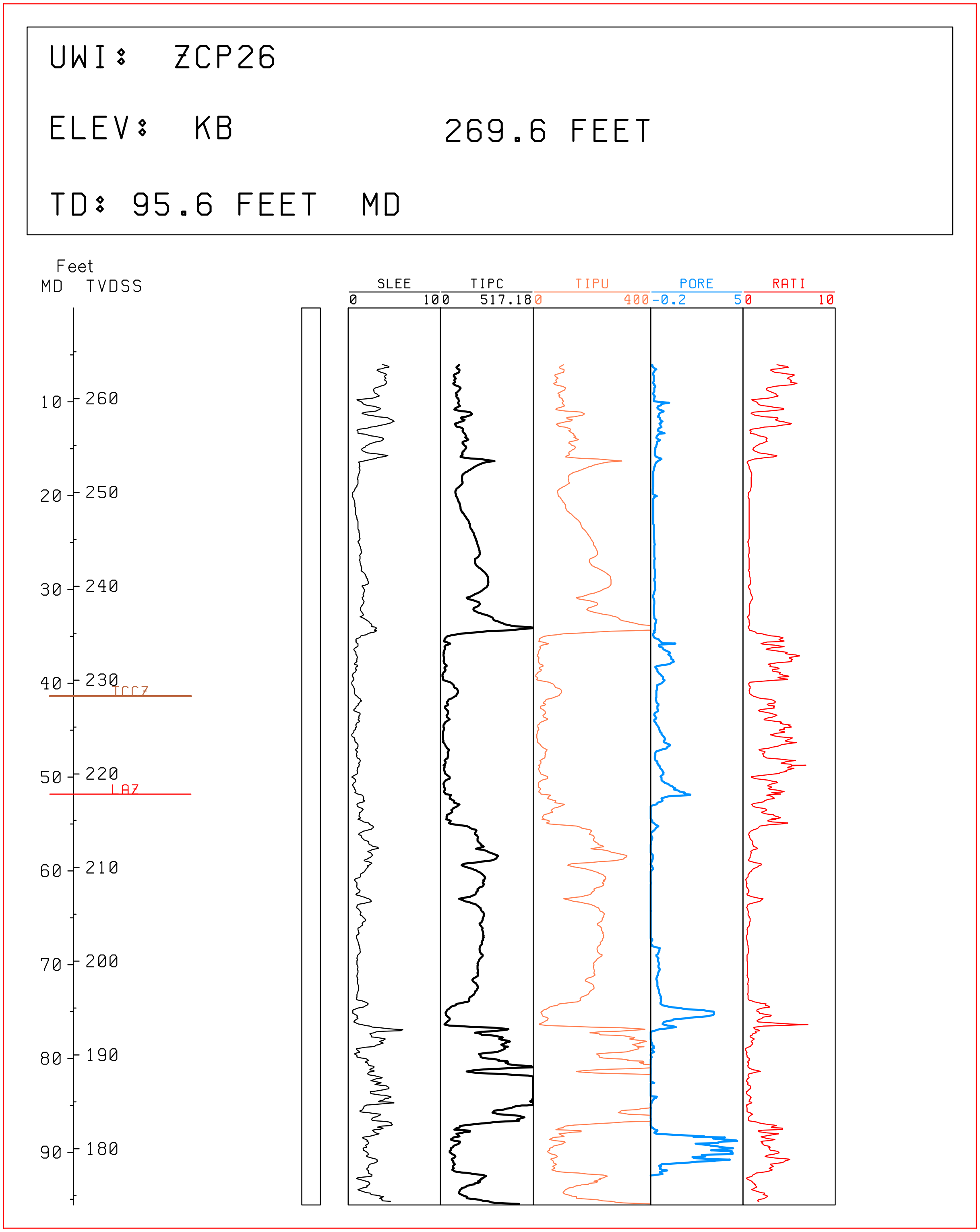


UWI: ZCP25

ELEV: KB 269.6 FEET

TD: 85.6 FEET MD

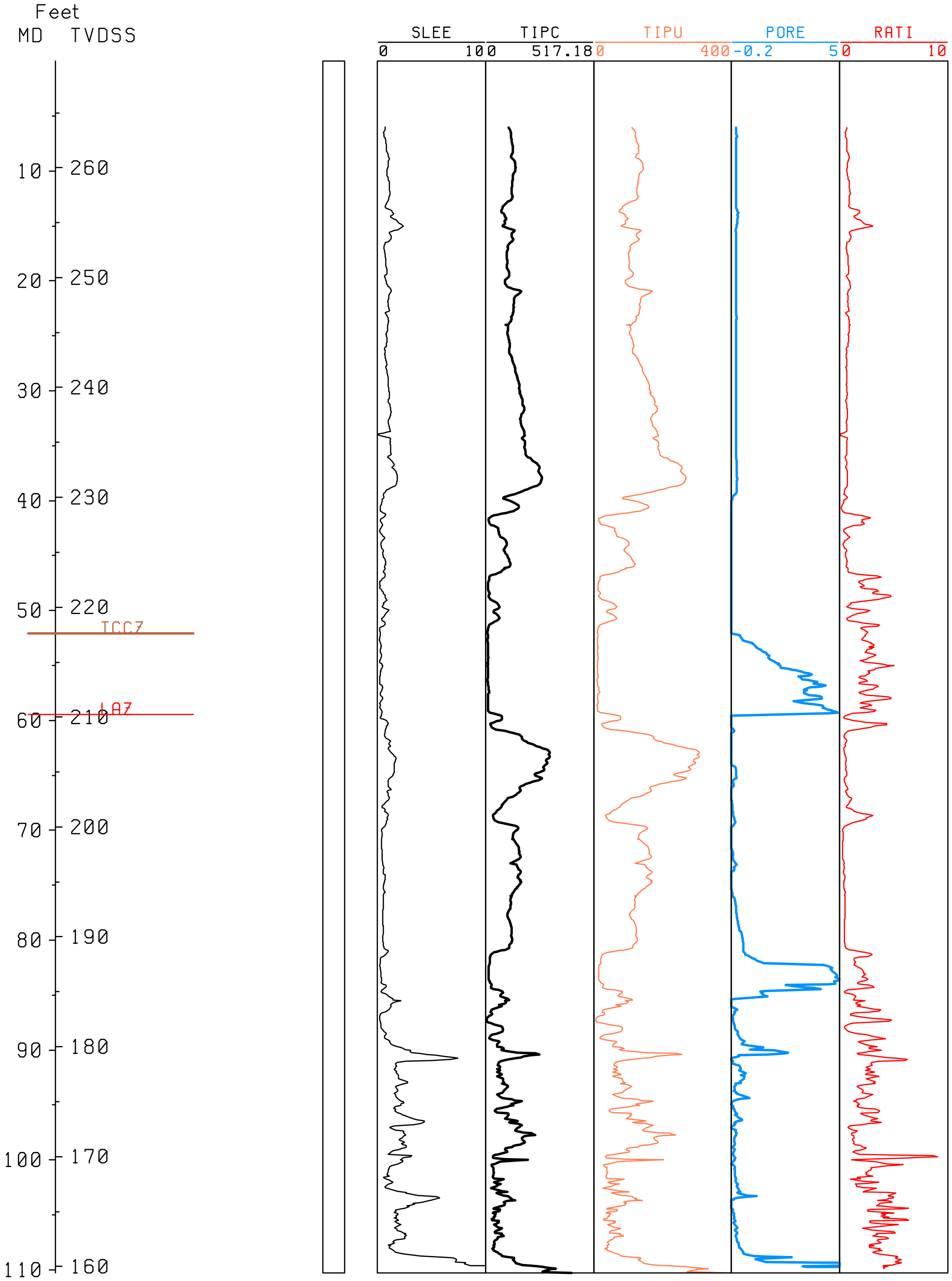



UWI: ZCP26
ELEV: KB 269.6 FEET
TD: 95.6 FEET MD
Feet
MD TVDSS
10 260
20 250
30 240
40 230
50 220
60 210
70 200
80 190
90 180
TCCZ
LAZ
SLEE
0 100
TIPC
0 517.18
TIPU
0 400
PORE
-0.2 5
RATI
0 10

UWI: ZCP27

ELEV: KB 269.7 FEET

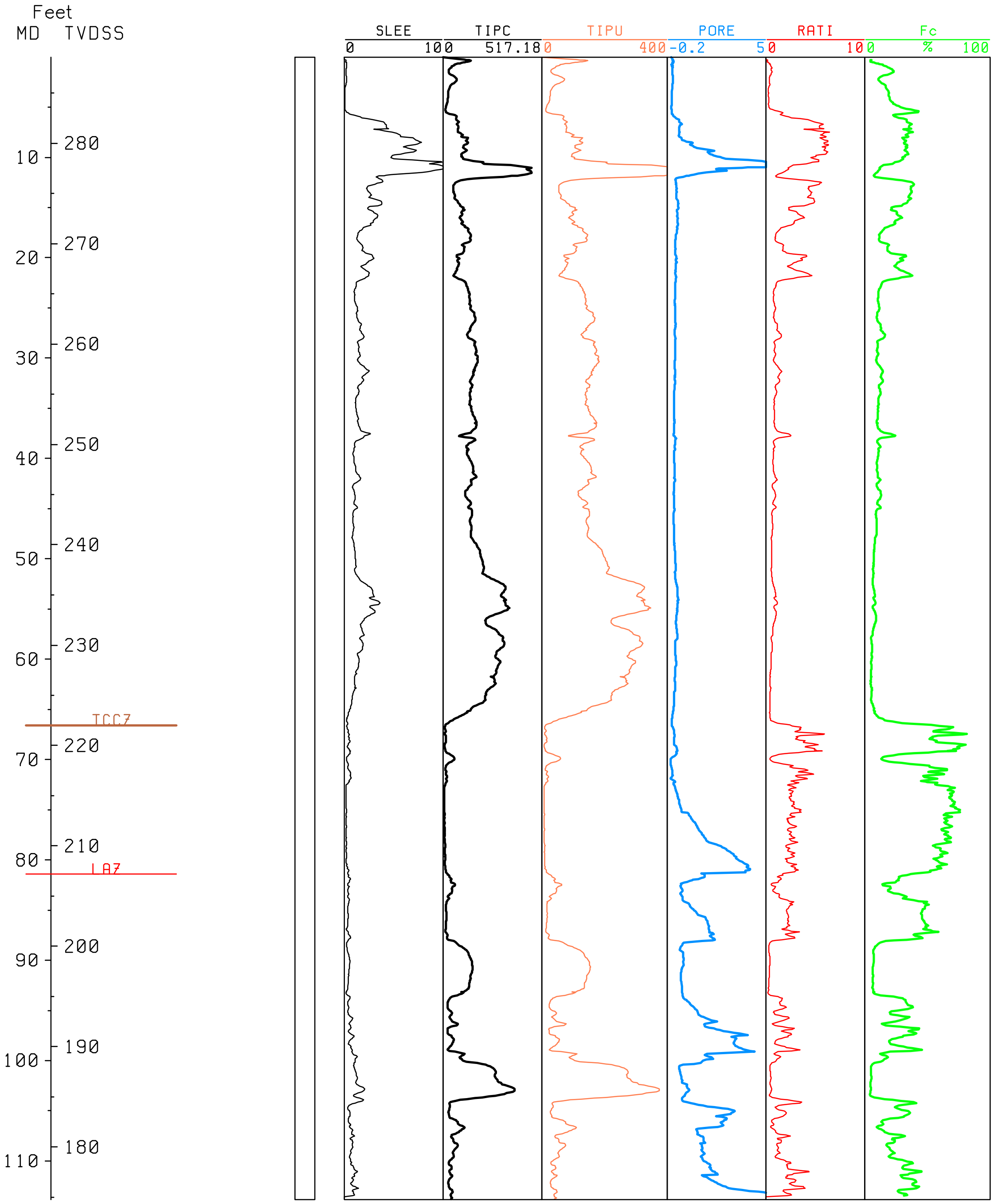
TD: 110.3 FEET MD



UWI: ZV2CP1

ELEV: KB 288.6 FEET

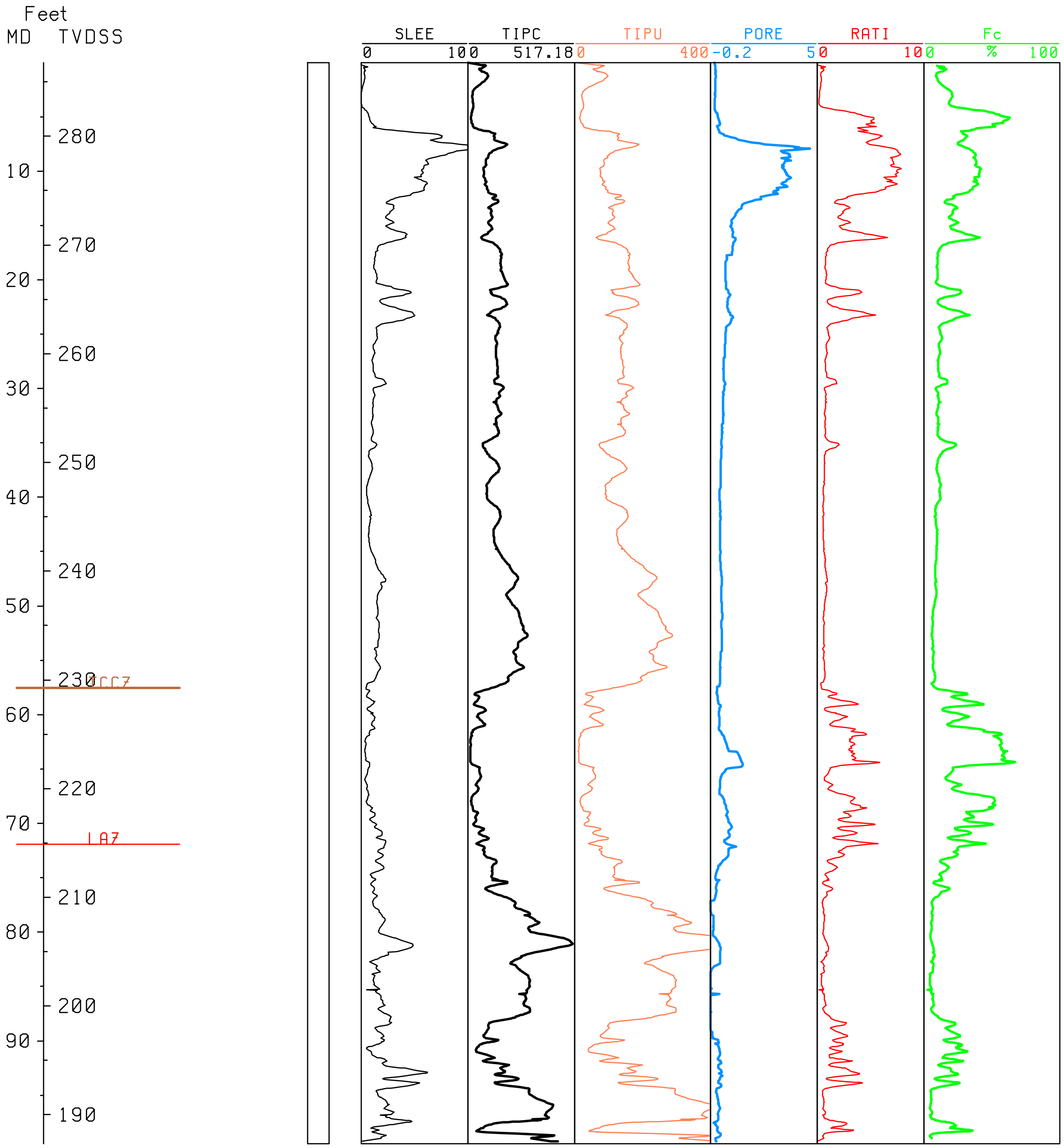
TD: 113.9 FEET MD



UWI: ZV2CP2

ELEV: KB 286.8 FEET

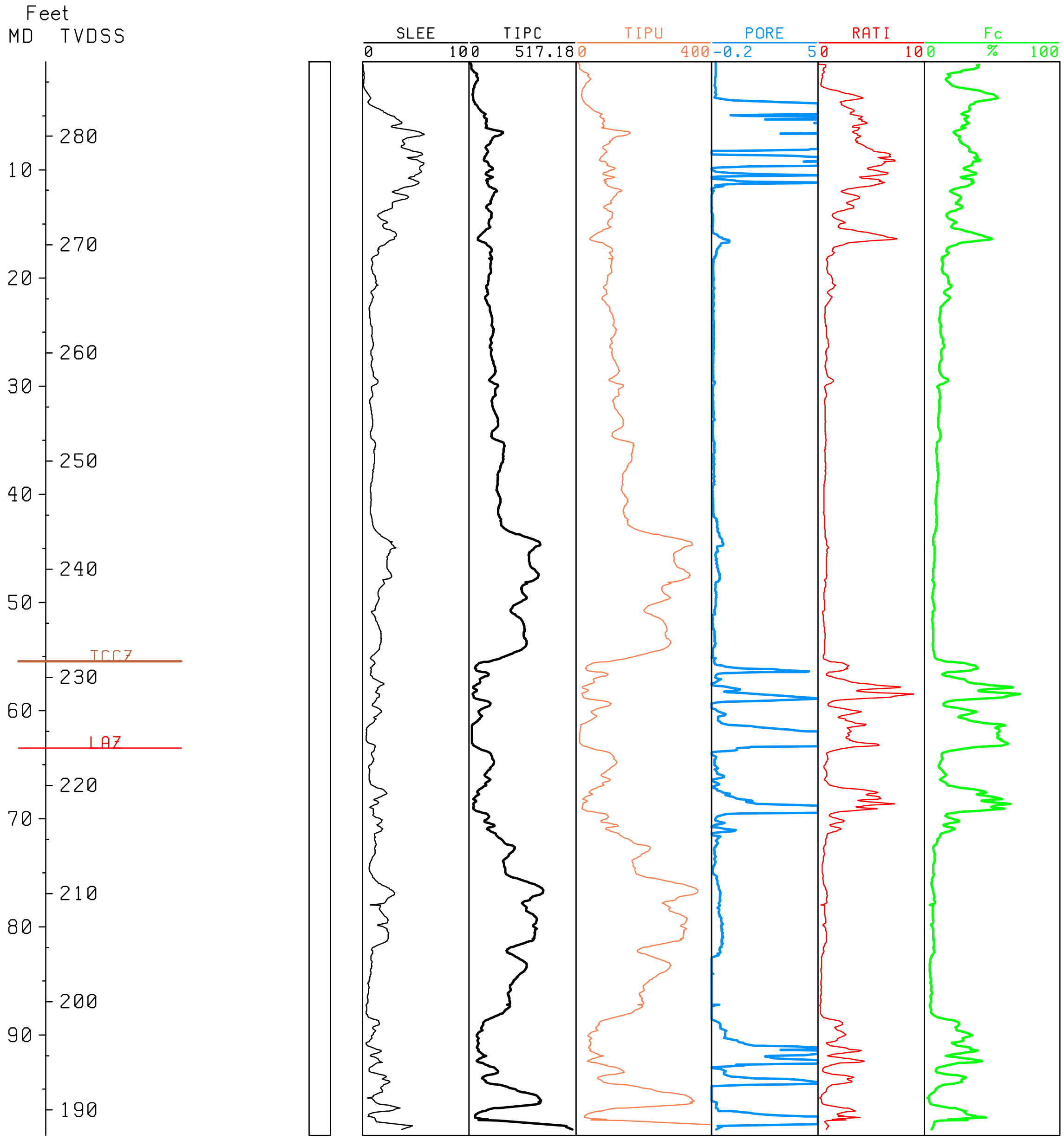
TD: 99.5 FEET MD



UWI: ZV2CP3

ELEV: KB 286.9 FEET

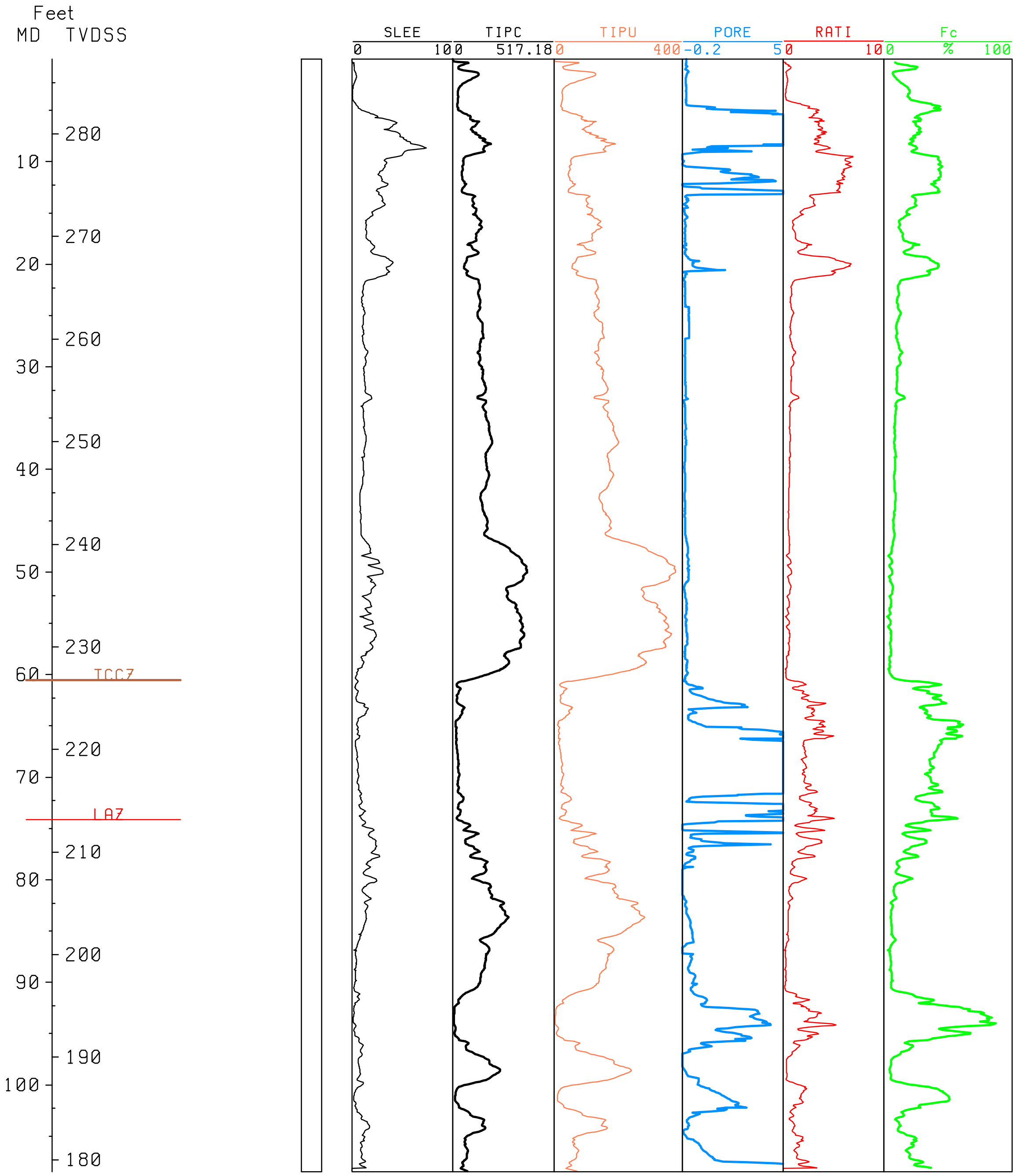
TD: 99.3 FEET MD

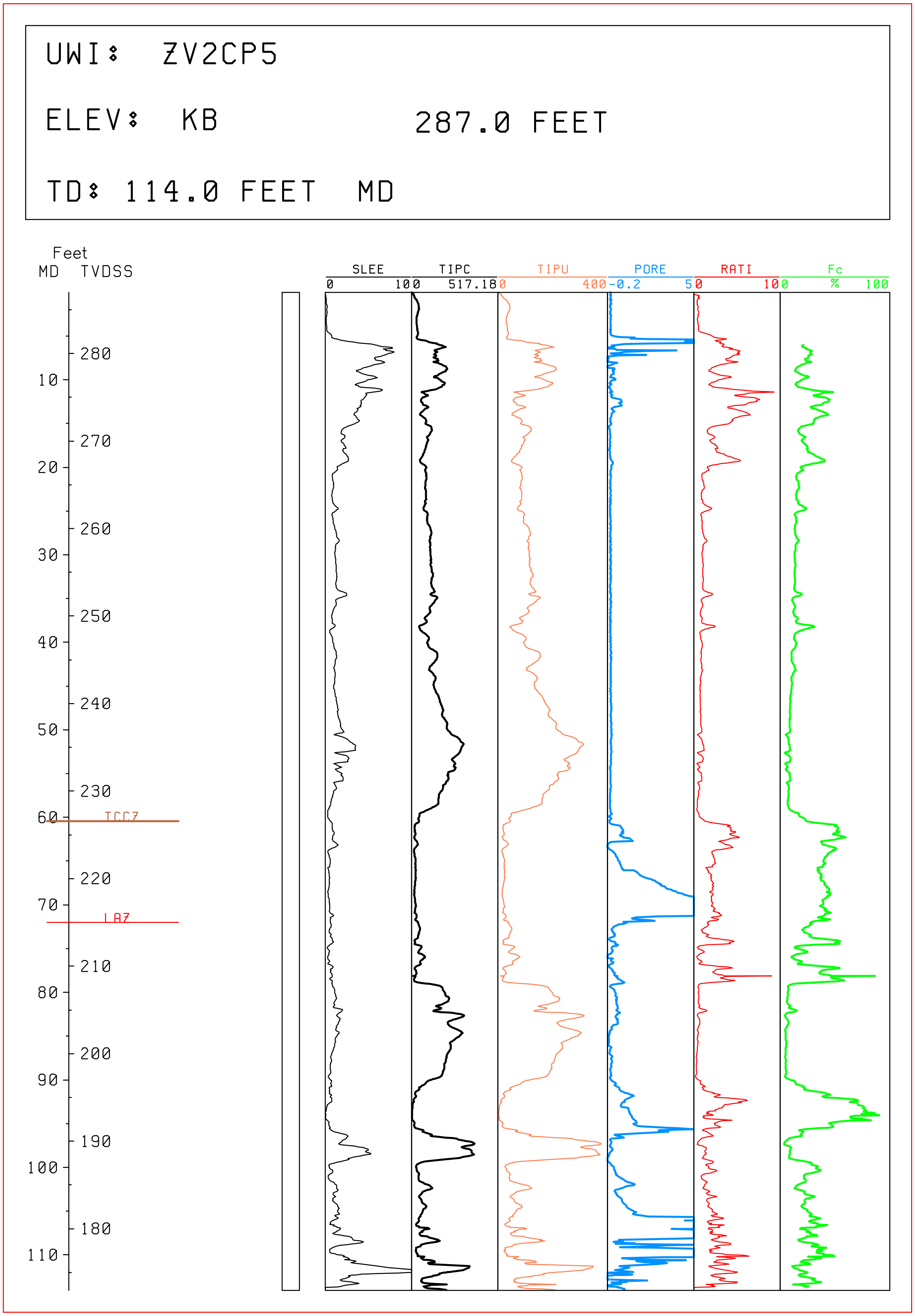


UWI: ZV2CP4

ELEV: KB 287.3 FEET

TD: 108.5 FEET MD

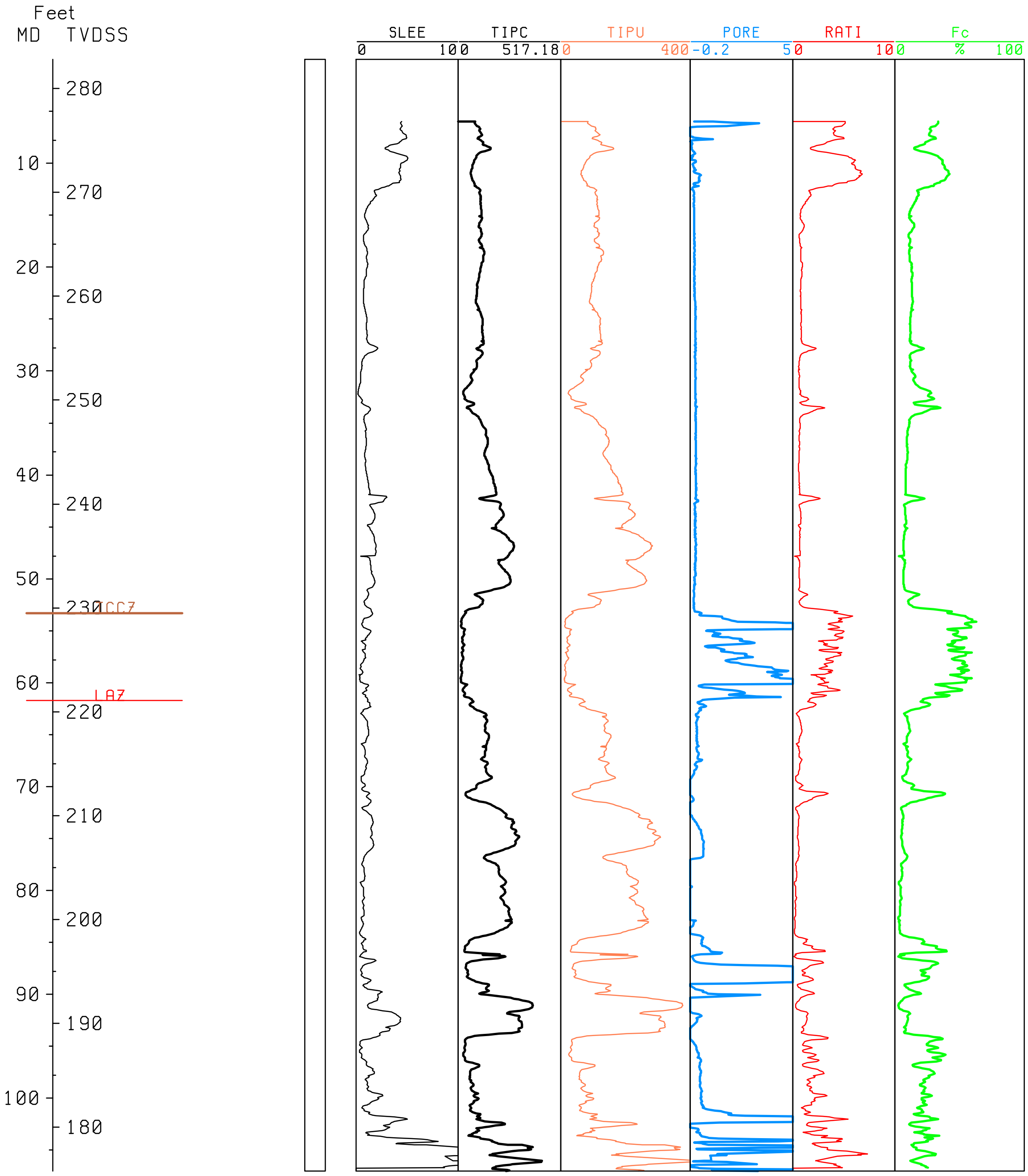



UWI: ZV2CP5
ELEV: KB 287.0 FEET
TD: 114.0 FEET MD
Feet
MD TVDSS
SLEE 0 100
TIPC 0 517.18
TIPU 0 400
PORE -0.2 5
RATI 0 10
Fc 0 % 100
TCCZ
LAZ
10 20 30 40 50 60 70 80 90 100 110
280 270 260 250 240 230 220 210 200 190 180

UWI: ZV2CP6

ELEV: KB 282.8 FEET

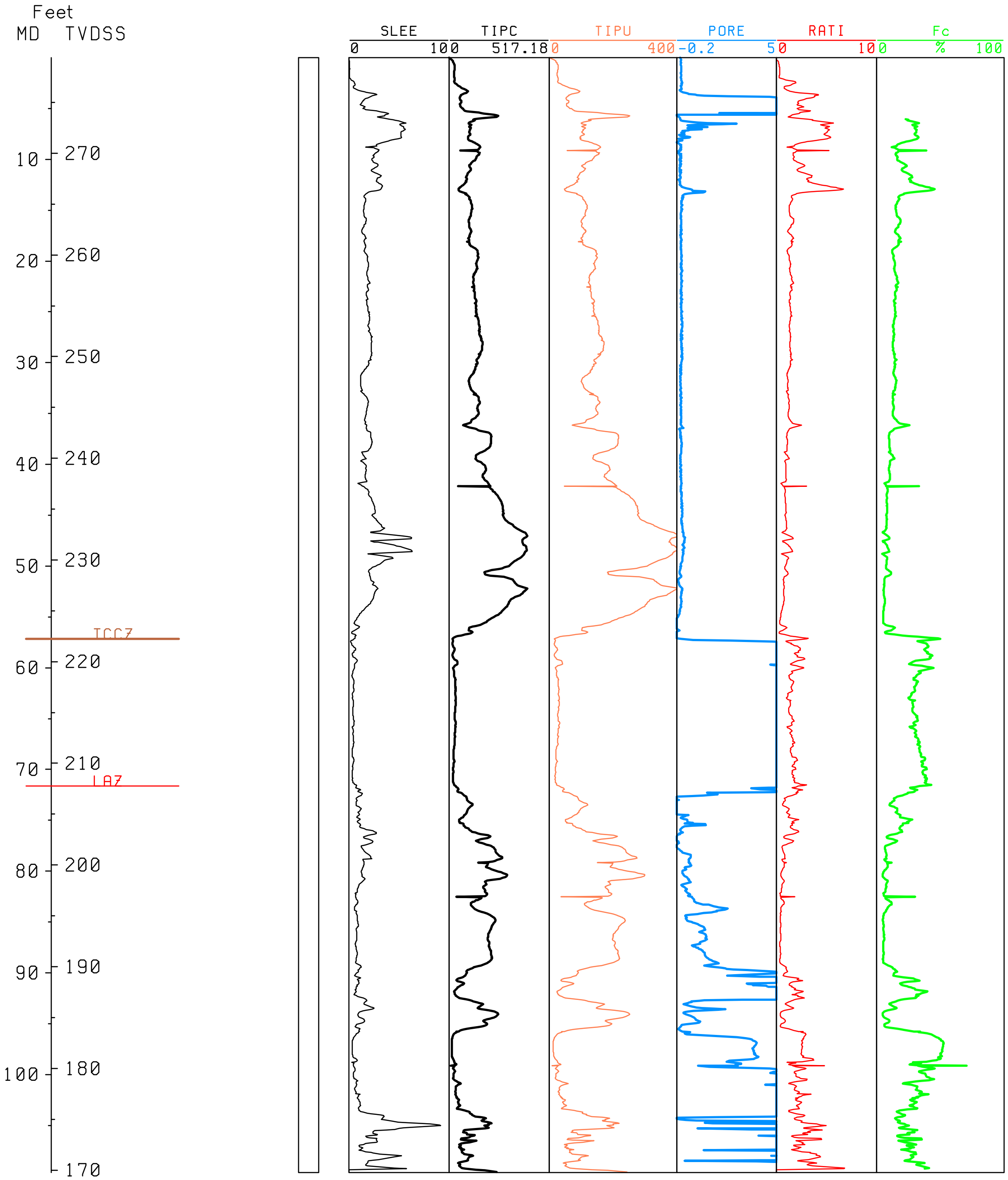
TD: 107.0 FEET MD



UWI: ZV2CP7

ELEV: KB 279.4 FEET

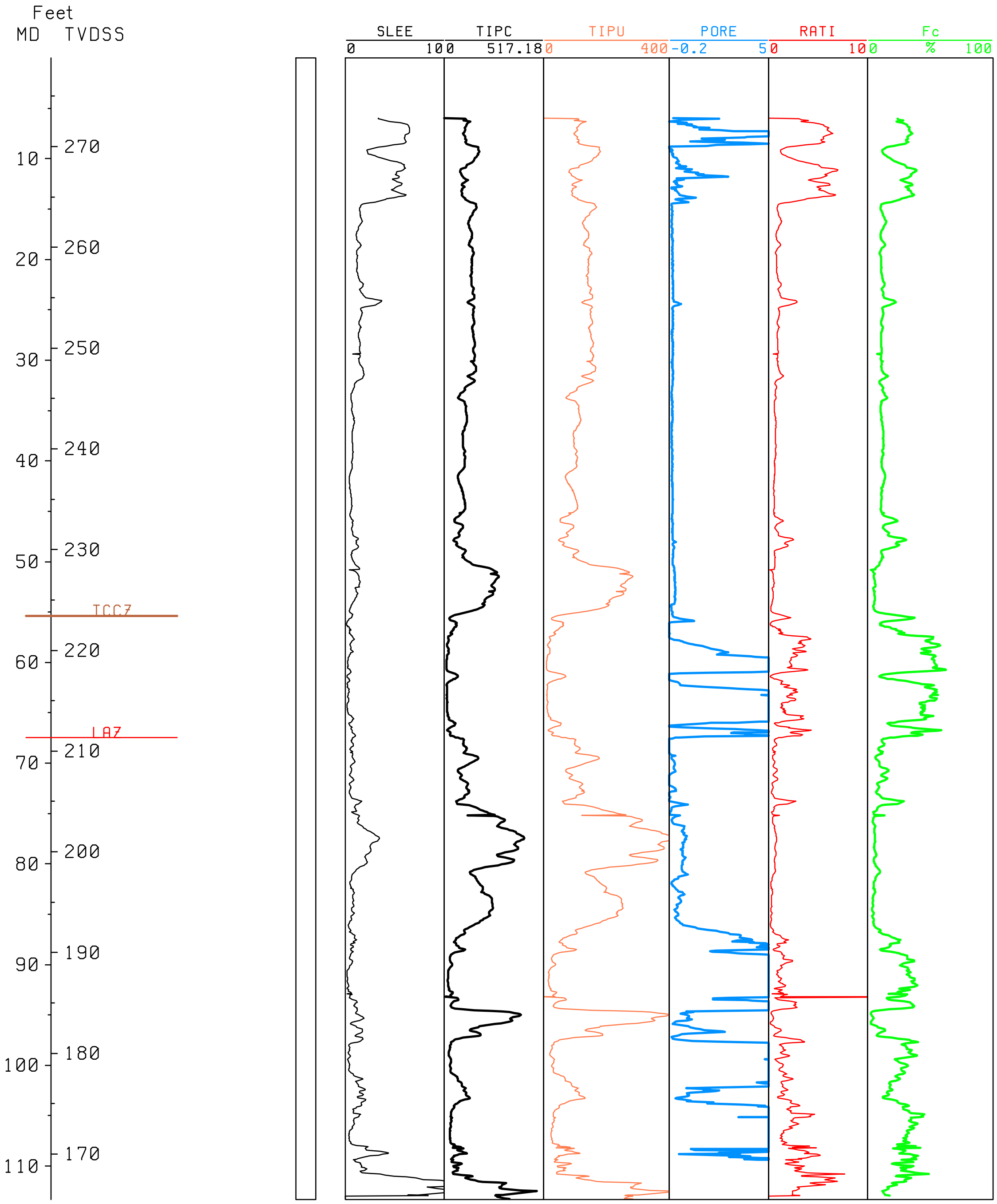
TD: 109.6 FEET MD



UWI: ZV2CP8

ELEV: KB 278.8 FEET

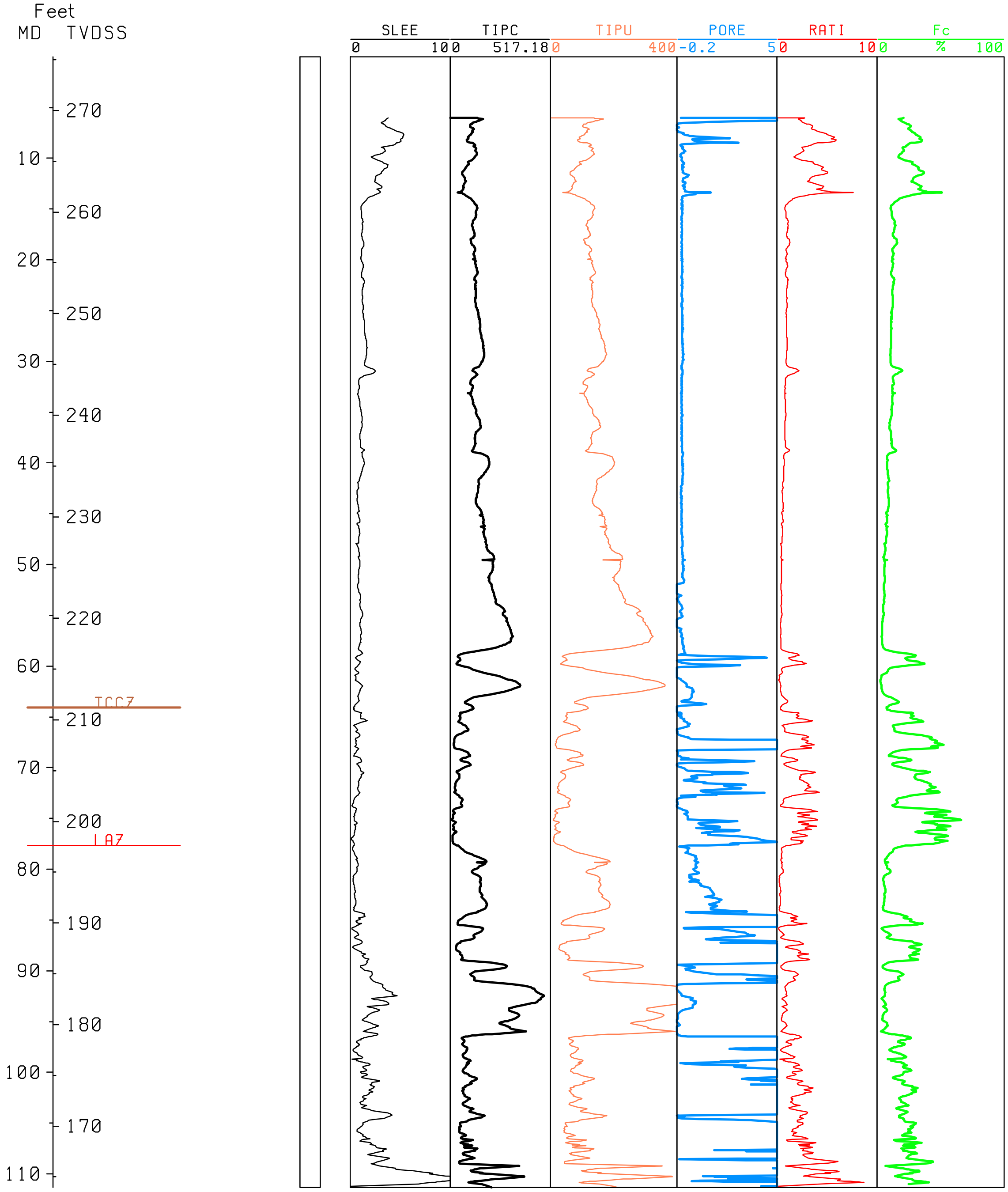
TD: 113.3 FEET MD

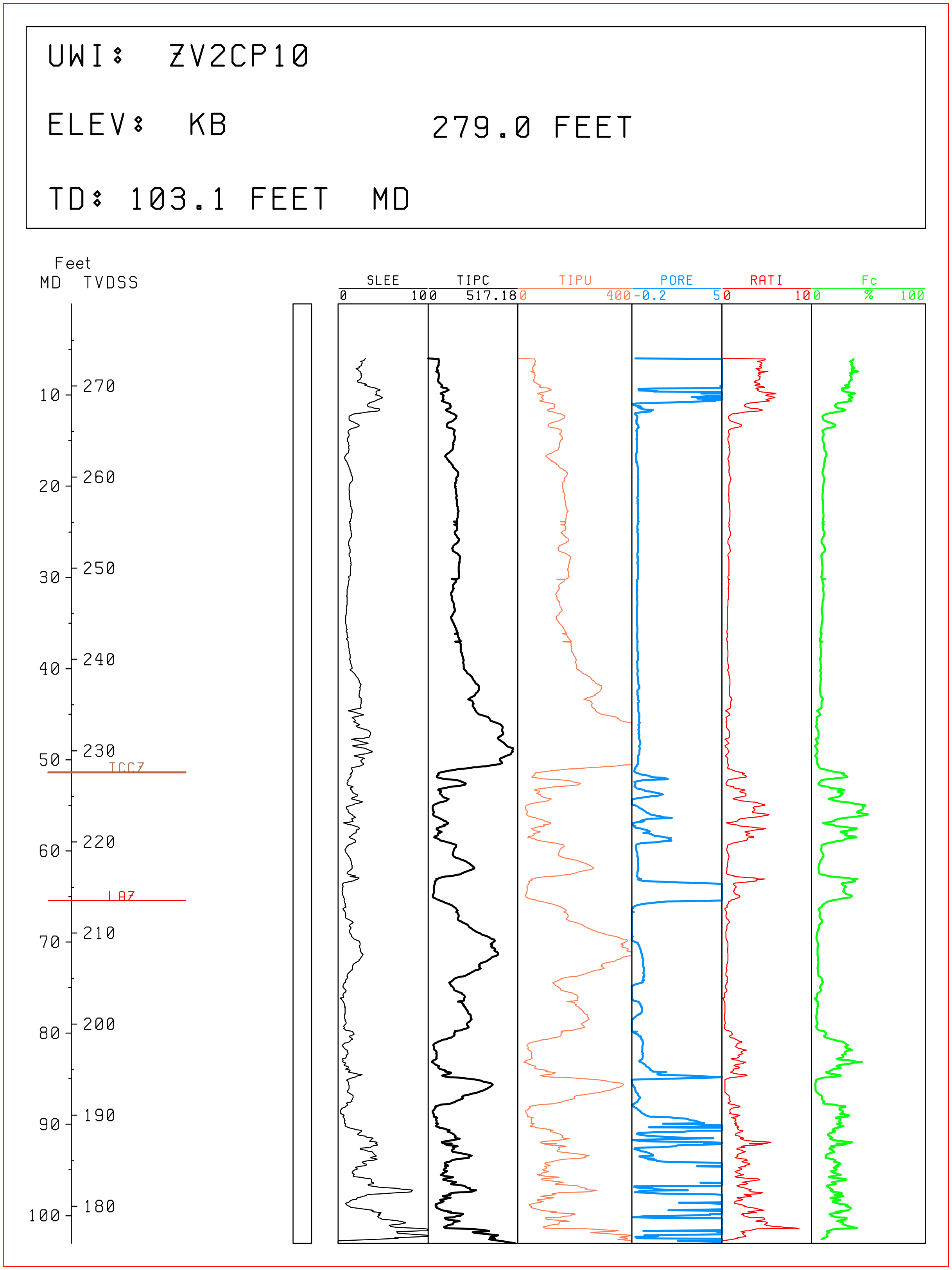


UWI: ZV2CP9

ELEV: KB 275.3 FEET

TD: 111.3 FEET MD

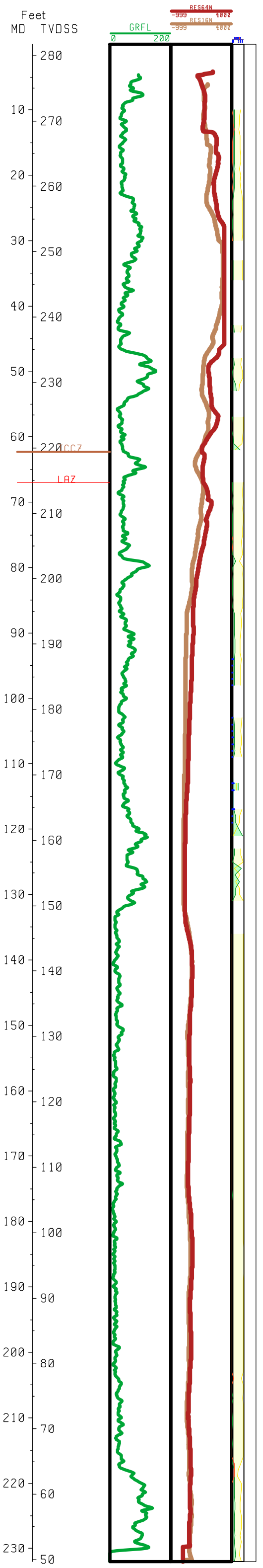



UWI: ZV2CP10
ELEV: KB 279.0 FEET
TD: 103.1 FEET MD
Feet
MD TVDSS
SLEE
TIPC
TIPU
PORE
RATI
Fc
0 100
0 517.18
0 400
-0.2 50
0 100
0 % 100
10 20 30 40 50 60 70 80 90 100
270 260 250 240 230 220 210 200 190 180
TCCZ
LAZ

UWI: YSC2A

ELEV: KB 281.7 FEET

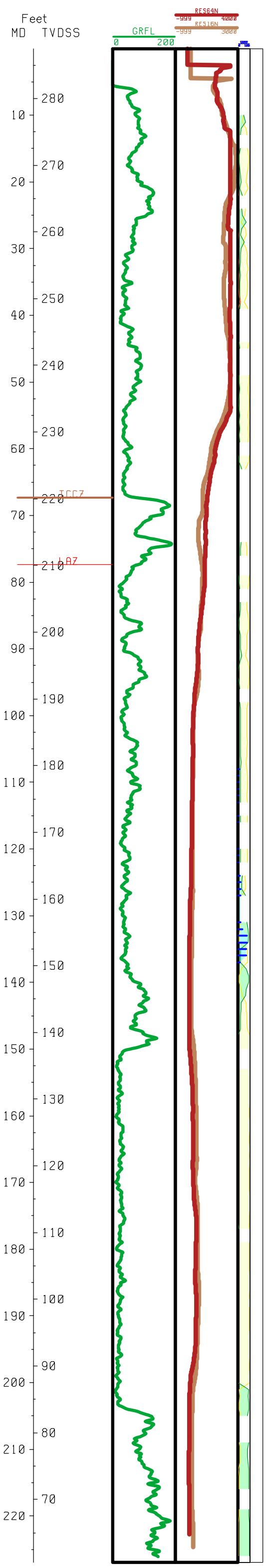
TD: 232.0 FEET MD



UWI: YSC4A

ELEV: KB 287.5 FEET

TD: 227.0 FEET MD



UWI: YSC5A

ELEV: KB 273.0 FEET

TD: 213.0 FEET MD